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THE BOTANICAL GAZETTE

Editor: JOHN M. COULTER

June 1913

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THE

BOTANICAL GAZETTE

JUNE 1913

TOXIC INORGANIC SALTS AND ACIDS AS AFFECTING PLANT GROWTH

(PRELIMINARY COMMUNICATION)

CHAS. B. LIPMAN AND FRANK H. WILSON

The economic and industrial phases of the smelter fume and smelter waste problem, especially as related to crop growing in the vicinity of smelters, have been accompanied by a revival of interest in the scientific aspects connected with the physiological effects of the metallic compounds of copper, lead, zinc, and others on plant growth. There have appeared in 1905, 1908, and 1910, respectively, Bulletins 89, 113, and 113 revised, of the Bureau of Chemistry of the United States Department of Agriculture, and all by J. K. HAYWOOD, dealing with the subject of smelter fumes and smelter wastes as related to plant and animal life. HAYWOOD points out in these not only the fact that smelter fumes (largely SO_2) are very toxic to trees and other plants in the country surrounding the smelters, but in the last two bulletins mentioned devotes some attention to the subject of copper compounds in smelter wastes as affecting the value of irrigation water and soils to be used for crop production. It was this latter fact, together with a desire on our part to obtain further information on the action of manganese in soils and its effects on plants, that led the authors to institute the preliminary experiments which are described below. Before reporting these, however, it is of interest to turn for a moment to a brief review of the results thus far obtained by plant

physiologists and chemists bearing on the subject under consideration.

The extreme toxicity of copper to plants under certain conditions has been responsible, it would appear, for some assumptions on the part of investigators as to the similarity in the action of copper in solutions and in soils. Thus JOHNSON, in his now classic work *How crops grow*, evidently assumes from the results obtained in solutions that copper is poisonous to plants even in very small quantities. Likewise the work of HEALD[1] and HARTER[2] with plants grown in solutions shows copper to be extremely toxic to plants. The former found, for example, that 1 part of copper in 404,423 parts of water was deadly to the garden pea (*Pisum sativum*), and that maize (*Zea mays*) seedlings are killed by the presence of 1 part of copper in 808,846 parts of water. OSTERHOUT[3] showed how water obtained from copper stills was poisonous to certain of the lower plants when containing merely traces of copper, and HAYWOOD, in the work above mentioned, states that in preliminary work with plants in soils containing copper, the growth of wheat and rye is "interfered with by the presence of 2.1 parts of soluble copper per million parts of earth in one soil, and by 3.5 parts of soluble copper per million parts of earth in another soil."

Some striking results on the effects of copper on plant growth which date back much farther than the last discussed were those obtained at the New York[4] and the Iowa[5] Experiment stations. It is a curious coincidence that both of these investigations were reported in the same year (1892), and they were both the result of the fungicide investigations in which it appeared of interest to ascertain how the continued use of fungicides would affect the soil in its productive capacity. In the New York bulletin, Part I of which is devoted to the subject in question, we find that among peas, wheat, and tomatoes, which formed the test plants, a resistance was noted to as much as 2 per cent and 5 per cent of $CuSO_4$ of the

[1] BOT. GAZ. **22**:125. 1896.

[2] Bur. Pl. Ind., U.S. Dept. Agric. Bull. 79. p. 40.

[3] BOT. GAZ. **44**:272 (footnote). 1907.

[4] N.Y. Exp. Sta. Bull. 41. 1892.

[5] Iowa Exp. Sta. Bull. 16. 1892.

dry weight of the soil, and while the soils free from copper gave much larger yields of fruit and vine than did those grown in soils containing copper, it is amazing to note such extreme resistance to large quantities of a poisonous compound on the part of plants as manifested by more or less growth. The author of the paper gives the results only as preliminary and promises a much more thorough review of the investigations later. Twenty years have passed since, however, and we are unable to find any further published data from the New York Experiment Station on that subject. One more note in the paper is of interest, and that is of a contemporary paper by HASELHOFF,[6] the conclusions of which are quoted, in which that author states among other things that soluble copper salts are injurious to plants, and that while concentrations up to 5 ppm. are harmless, the presence of 10 ppm. of copper in soil has a marked retarding action. In the Iowa bulletin by PAMMEL we find that copper solutions had a marked retarding effect on the root development of plants, and that no roots at all developed where the concentration of copper was large. It is unfortunate that PAMMEL does not make mention of the concentrations of copper existing in the various experimental plots in the greenhouse.

So far as the effect of zinc salts on plant growth is concerned, there is but meager information. We have, however, the recent investigations in Germany on the effect of the zinc in galvanized iron cylinders, used for vegetation experiments, on plant growth. From these it would appear that zinc may be distinctly toxic to plant growth.

Experiments with manganese, however, have been very numerous; but their results have been so conflicting as to make more experimental work very desirable. The reader is referred for a more complete bibliography on the effects of manganese in soils on plant growth to a recent publication by W. P. KELLEY.[7]

Along with the problems of smelter fumes and smelter wastes, has come the idea of the condensation of the sulphur dioxide and the manufacture of H_2SO_4. It has been calculated by COTTRELL and others, however, who have made a careful study of the problems,

[6] Landw. Jahrb. **21**:263.

[7] Hawaii Exp. Sta. Bull. 26.

that the amounts of H_2SO_4 thus produced would be so enormous as to make it useless, since the demand for the acid is as yet quite limited. It has been suggested, therefore, among many other proposed uses for it, that H_2SO_4 be used in small quantities in the irrigation water to act as a solvent for soil minerals. It was this idea which suggested the preliminary experiment described below, along with the others, on the effects of the metallic salts on plant growth.

Experiments

The soil employed in the experiments was a light sand with a good humus supply, and was constituted chemically as follows:

Insoluble residue	75.77 per cent	Mn_3O_4	0.01 per cent
Soluble silica	2.94	P_2O_5	0.26
Fe_2O_3	2.05	MgO	0.36
Al_2O_3	3.38	Na_2O	0.17
CaO	1.59	K_2O	0.45
SO_3	0.02	Humus	2.35

Large 8-inch flower pots were filled with 12 lbs. of soil and treated with varying amounts of the solution of the salt to be tested, each cc. representing a known weight of the salt. The concentrations employed are noted in the tables in parts per million of water free soil. The plants tested were the vetch (*Vicia sativa*) and the Little Club variety of wheat. Eight seeds, which were carefully selected, were planted in each pot, and after some growth was made were thinned to 4 plants per pot. The pots were carefully irrigated so as to give the soil an optimum moisture content but not allow any moisture to percolate from the soil, thus preventing loss of the salts tested. The plants were all grown under glass and appeared to make good vigorous growth from the start. The appearance of the aphis and other insects in large numbers undoubtedly had something to do with diminishing the total yield of dry matter, but not enough to affect the results seriously. The vetch was not allowed to mature, but had to be harvested about the same time that the wheat was cut, because the mildew had attacked the plants rather seriously. The wheat was mature, however, when harvested. In the case of the vetch, the weight of the tops, as well as that of the roots, is given, while in the case of the wheat, only the

weight of the tops as dry matter is recorded. The following tables give all other explanatory data and results of the experiments, and a discussion follows each table.

TABLE I

EFFECTS OF $CuSO_4$ ON PLANTS

$CuSO_4$ ppm.	DRY WEIGHT OF VETCH		DRY WEIGHT OF WHEAT
	Roots gm.	Tops gm.	Tops gm.
0	4.5	12.0	18.5
5	1.8	20.5	15.7
10	5.5	20.0	16.2
20	4.0	21.0	17.5
40	5.5	17.5	13.0
100	3.0	18.0	16.5
200	4.5	14.0	17.2
400	Det. lost	12.0	19.0
600	...	....	12.7
1000	1.5	13.0	9.7

To one accustomed to regard $CuSO_4$ as an extremely poisonous salt for plants, the data in table I offer a surprise. While it is true that in the case of the wheat no stimulation from $CuSO_4$ is evident, its toxic nature likewise cannot be said to manifest itself until a concentration of 1000 ppm. is reached, if then. The last phrase is used advisedly, since the plants in the 600 and 1000 ppm. concentrations of $CuSO_4$ were started three weeks later than the rest. Germination of the wheat seeds seemed to proceed with much greater rapidity in the higher concentrations, but the plants though growing fast did not seem to possess the deep green color which is so characteristic of plants well nourished. These plants, however, matured at about the same time as the other wheat plants growing in the lower concentrations of $CuSO_4$, and produced normal heads.

In the case of the vetch plants, there seems to have been a stimulation due to $CuSO_4$, and then what might perhaps be looked upon as toxicity in the highest concentrations. It should be noted, however, that here, as in the case of the wheat, the vetch plants growing in the higher concentrations of copper were planted three weeks later than those growing in the soils with lower concentrations

of copper. It is especially interesting here to mention the rapid and rank growth made by the vetch plants in the highest concentration of copper. All the seeds germinated and the vetch plants seemed to grow erect to a height of 6 inches or more before they began to bend downward by their own weight. The plants in the normal soil and in those with low concentrations of copper made but very little upright growth. One further point is of great interest in regard to the vetch plants, and that is that even at the highest concentrations of copper, the root development appeared to be normal and showed a marked and vigorous development of nodules (the soils were all inoculated). In general the effects of the copper sulphate as given in table I stand out in sharp contrast with the results above reviewed. They exhibit, on the one hand, a very much greater resistance to the effects of copper on the part of both wheat and the vetch plants than HAYWOOD observed in the case of wheat and rye as above noted; and on the other hand, our observations on the plants growing in the highest concentrations of copper given in table I lead us to believe that they will not withstand amounts of copper at all to be compared with those tolerated by the plants with which the experiments at the New York Experiment Station were carried out. From our results it would appear that the use of irrigation water containing a few parts of copper per million would not for many years react deleteriously to plant growth, while the very reverse is believed by HAYWOOD on the basis of his results. Further results were promised by HAYWOOD in 1908 based on his experiments with soils, but none have as yet appeared.

With reference to the cause of the injurious action of copper there are two explanations. One shows that there is direct injury due to absorption of copper as manifested by analysis, and frequently showing a large quantity of copper in plants sprayed with fungicides or in those growing in soils with a high copper content. HASELHOFF, however, whose work is cited above, claims that his investigations indicate an increased solution of lime and potash and subsequent leaching away of these materials through the action of copper sulphate, and that injury can be averted by applications of $CaCO_3$ to replace the losses taking place as indicated.

The next series deals with the effects of $ZnSO_4$ on plants. The experiment was arranged similarly to the preceding, but the concentrations are slightly different, as shown in table II.

TABLE II

EFFECTS OF $ZnSO_4$ ON PLANTS

$ZnSO_4$ ppm.	DRY WEIGHT OF VETCH		DRY WEIGHT OF WHEAT
	Roots gm.	Tops gm.	Tops gm.
0	4.5	12.0	18.5
10	1.5	12.5	17.5
20	3.0	20.0	18.5
100	4.5	22.0	18.5
200	4.5	20.0	14.6
300	2.0	20.0	10.8
400	1.8	18.0	19.8
500	1.5	15.5	13.7

These results do not show any marked toxicity of $ZnSO_4$ either for the vetch or the wheat. In the case of the vetch, there would even seem to be an appreciable degree of stimulation up to rather large concentrations of zinc. We can certainly not confirm any toxic effects of zinc salts on plants observed by others, at any rate so far as the concentrations employed above are concerned. The seeds germinated in the zinc-treated soils in a normal manner, and the plants in all the concentrations of the $ZnSO_4$ seemed to make a normal growth. Whatever differences may be noted in table II between the growths made in the pots of the different concentrations of salt employed must be attributed to insect or fungus injury rather than to any effect of the $ZnSO_4$. A comparison of our results with the effects of zinc noted by EHRENBERG, whose work is above cited, would seem to indicate that the later investigations[8] attribute both favorable and unfavorable effects to the zinc dissolved out from the galvanized iron cylinders used in the vegetation experiments. EHRENBERG claims that zinc acts favorably in that it displaces the bases from their insoluble combinations, and because of its harmful effect on soil organisms makes less competition for the plant in the latter's search for soil nitrogen. On the other hand, the same author points out that zinc sets free hydroxyl ions which exercise

[8] Landw. Versuchs. **72**:15. 1910.

a corrosive effect on plants, and that a too rapid displacement of bases in the soil and their subsequent leaching tends to cause soil acidity.

It is to be regretted that EHRENBERG'S researches were carried out from the point of view merely of establishing the feasibility of employing vegetation cylinders containing zinc, and therefore we have nothing to guide us to the extent of the solution of zinc and the toxic limit thereof. It appears to us, further, that it is begging the question to assert that the toxic effect of zinc on soil organisms is of benefit to plants for the reason mentioned, because we have no definite data concerning the effects of zinc on soil bacteria or other soil organisms, and certainly not evidence enough, so far, to point to wide differences between the effects of zinc on the higher plants and soil bacteria. From the data in table II, at any rate, it would appear that plants will tolerate and will not be affected by even very considerable quantities of zinc. In connection with this series of experiments in particular, it is desirable to have more experimental data, which we are attempting to secure in further experiments now under way.

The numerous and conflicting results obtained by different investigators in the study of the physiological effects of manganese salts on plants made it desirable to work further with these interesting compounds, and an experiment was arranged, therefore, in which this problem could be studied. The arrangement of the experiment with the results obtained are given in table III.

TABLE III

EFFECTS OF $MnSO_4$ ON PLANTS

$MnSO_4$ ppm.	DRY WEIGHT OF VETCH		DRY WEIGHT OF WHEAT
	Roots gm.	Tops gm.	Tops gm.
0	4.5	12.0	18.5
20	4.0	9.5	16.2
40	3.5	11.5	20.0
80	6.0	15.0	21.5
200	4.0	18.0	25.1
400	5.0	17.5	23.2
800	5.5	19.5	26.0
2000	3.5	10.0	32.5

It is clear from the data given in table III that both wheat and vetch are stimulated by the presence in the soil of $MnSO_4$ until the concentration of the latter there reaches an equivalent of 2000 ppm. for the wheat and 800 ppm. for the vetch. Indeed, the total yields of dry matter obtained from the wheat growing in the pots with the highest concentrations of $MnSO_4$ surpass quite markedly the yields obtained in any of the pots of the other series described in this paper, and which were planted contemporaneously with the former. In the case of the vetch, the stimulation does not seem to be as great as in the case of the wheat, but from one series of experiments it is difficult to say if stimulation actually stops for the vetch at a concentration of 2000 ppm. of $MnSO_4$, since the poor growth obtained there may have been due to experimental error.

These results are an interesting contribution to the subject of the effects of manganese salts on plants. It is not our intention here to discuss the large number of investigations bearing on this subject, especially since this has already been so well done by KELLEY, in the work above referred to. In general, however, it would appear from such a review that the largest number of investigations on the subject indicate a stimulating power of manganese sulphate for plants, results with which ours are in accord. There are several cases, however, in which manganese compounds have been observed to depress crop yields, and this point would seem particularly to deserve brief discussion. The experiments dealing with this subject which have thus far been carried out have included tests of many different manganese compounds, and a comparison of the results obtained with different compounds in trying to determine the specific effects of manganese would seem to us to be manifestly unfair. One of us has pointed out elsewhere[9] that the anion as well as the kation of salts must be taken into consideration when the effects of salts on living organisms are studied. If such be the case, and we have every reason to believe that it is, then only the experiments bearing on the effects of $MnSO_4$ on plants should be compared when that subject is studied, and not the effects of the nitrate, chloride, oxide, sulphate, and other compounds. When that is done, it will be found that the percentage of investi-

[9] Centr. Bakt. **33**:305.

gations dealing with the subject under discussion in which $MnSO_4$ has not been found, in relatively small quantities, to act as a stimulant is indeed very small. Obviously when very large concentrations of $MnSO_4$ are employed it will be found toxic. As investigations of KELLEY above referred to have shown, a large variety of plants is affected more or less seriously by the manganese of soils which have shown a content of that material equivalent in some cases to more than 9 per cent of Mn_3O_4 in the soil. However, such manganiferous soils are limited in extent and, undoubtedly even then, owe their unfavorable nature, in part, to the form of the manganese which they contain. This point appears to us so important as to render a comparison of past results on manganese investigations of little value when it is not considered. It would seem from our results in this series of experiments, and others of a similar nature which they help to confirm, that distinct increases in crop yields of certain plants may be induced by employing $MnSO_4$ in small quantities as a soil amendment. The manganese content of most "normal"[10] soils is very small, and therefore the dangers arising from the presence of large amounts of manganese, as KELLEY has observed them on certain Hawaiian soils, are certainly very remote ones when considered in relation to these normal soils. Small additions of manganese should increase yields, therefore, without introducing dangers. We hope to report further results on this subject later.

As was pointed out above, it has been suggested by some chemists, among the many other uses proposed for H_2SO_4 when it is produced in enormous quantities from the SO_2 of the smelter fumes, that it could be employed in small quantities in the irrigation water, and, through the solution of mineral plant foods in the soil, be a considerable aid to the nutrition of plants directly, besides exerting perhaps a very marked influence indirectly on soil fertility as will be discussed later. In connection with soils containing black alkali, sulphuric acid would have an added value, if it were satisfactory in other ways, in that it would change the black to the white alkali more cheaply than gypsum does, and it could be applied more easily with irrigation water. Indeed, it is possible that in soils with a content of Na_2CO_3, not too large, the sulphuric

[10] Soils ordinarily cropped.

acid treatment of soil may prove a valuable practice. The following experiment was considered, therefore, of very great interest as a preliminary test of the physiological effect of H_2SO_4 on plants, and its arrangement and results are set forth in table IV.

TABLE IV

EFFECTS OF H_2SO_4 ON PLANTS

H_2SO_4 ppm.	DRY WEIGHT OF VETCH		DRY WEIGHT OF WHEAT
	Roots gm.	Tops gm.	Tops gm.
0	4.5	12.0	18.50
50	5.5	15.0	12.20
100	6.0	15.5	16.65
200	3.5	8.0	18.50
300	4.0	19.5	20.50
400	4.0	17.0	10.50
600	5.0	15.5	26.20

The foregoing data would seem to indicate that considerable amounts of H_2SO_4 may be added to soils without injury to plants. The objection, of course, to which such additions of acid would be open to in practice, is that when the lime and other bases have been neutralized in the soil by the acid, any further additions to the latter would tend to make an acid soil which is unfavorable for plant growth, but it is at any rate safe to assume that on strongly alkaline soils, where that condition is the interfering fact with plant growth, the acid treatment of soil should ameliorate its unfavorable condition to a marked degree. Moreover, we are not without a basis in fact for our assumption. SYMMONDS[11] has shown that when nitric acid to the extent of 600 pounds per acre was mixed with artesian water and applied to soils containing alkali, the yields of crops were greatly increased. It may be argued, of course, that this case is not an analogous one, since the nitric acid combines with bases in the soil to form nitrates which are an important food and even stimulant to plant growth, but it should also be remembered that, as one of us has already pointed out elsewhere, in a publication above cited, on the basis of direct investigations, that Na_2SO_4, produced through the action of H_2SO_4 on Na_2CO_3 (black alkali), is a stimulant to nitrification, and that thus an application of

[11] Agric. Gaz. N.S. Wales **21**:257–266.

H_2SO_4 to soils would render a service to the plant different in degree only but not in kind from that rendered by the application of HNO_3.

General remarks

While we offer the results given above as a preliminary report merely, on a series of investigations which we trust will ultimately make a thorough survey of the subject, we must conclude from these data that the tolerance of plants for certain of the inorganic salts, commonly regarded as very poisonous, is much greater than we have been wont to believe. It is true that we have commonly accepted the idea that very small quantities of poisons may act as stimulants, but our results show that plants do not merely tolerate but are actually stimulated by quite considerable quantities of these toxic salts. It is very desirable, therefore, to arrive at a definite understanding of the limits of toxicity of the substances in question, which we are now endeavoring to do.

It would appear to us, further, that the results we have obtained are sufficient evidence to prove that a more thorough investigation into the effects of smelter wastes on plants is necessary before we are enabled to determine justly whether from that standpoint smelter plants are inflicting appreciable injury on the soils immediately surrounding them and on the soils of contiguous territory.

Our results on the effects of $MnSO_4$ are considered of importance here both because of the stimulating effect of the former on plants and the attempts which have been made to make use of that fact in the employment of manganese salts as fertilizers. Moreover, our data form another link in the chain of evidence which show the stimulating effects of manganese sulphate on plants.

It may not be amiss to add here, also, that to make these investigations more complete we have been making studies of the bacterial flora in the soils employed in the experiments above described. From these we have already obtained data of great interest, which seem to indicate that the soil flora is permanently modified by the treatment of the soil outlined above. The publication of these results is reserved for another paper.

SOILS RESEARCH LABORATORY
UNIVERSITY OF CALIFORNIA

THE TRANSPIRATION OF APPLE LEAVES INFECTED WITH GYMNOSPORANGIUM[1]

HOWARD S. REED AND J. S. COOLEY

(WITH ONE FIGURE)

The present paper reports the results of some studies upon the transpiration of apple leaves infected with the cedar rust fungus, *Gymnosporangium Juniperi-virginianae* Schw. Observation of trees attacked by this fungus shows that changes involving serious injury to the economy of the trees are produced. Such trees usually show characteristic dwarfing of both trunk and fruit.

The writers have undertaken to make some quantitative physiological studies upon these diseased trees as a part of a general pathological problem.

The study of the causative organism is highly important for plant pathology if any prophylactic measures are to be taken, but the reaction of the host is also a factor of importance if the action of the parasite is to be understood, or if efficient remedial measures are to be applied. The interest of the cultivator is principally in the host, but up to the present time that of the plant pathologist has been chiefly centered in the parasite. It is believed, however, that a physiological-pathological study of the host will yield results of no less interest than those of a strictly mycological nature.

A survey of the published work upon transpiration discloses few studies of the transpiration of diseased plants, although the assumption is frequently made that the rate of transpiration is affected by the presence of disease.

BLODGETT[2] has reported an observation upon the transpiration of excised branches of *Rubus* sp. infected with *Gymnoconia interstitialis*. In a given period (apparently shorter than 24 hours) the rusted branch absorbed 42 cc. of water, while a healthy branch possessing an equal number of leaves absorbed only 23 cc. of water

[1] Paper 24 from the Laboratory of Plant Pathology, Virginia Agricultural Experiment Station.

[2] BLODGETT, F. H., Transpiration of rust-infected *Rubus*. Torreya 1:32. 1901.

under similar conditions. In spite of the greater amount of water absorbed, the rusted shoot was more or less flaccid, while the healthy shoot maintained a turgid condition. This behavior might be regarded as a consequence of the condition produced by the caeoma type of sorus produced by the fungus in question. The rupture of more or less extensive areas of the ventral epidermis of the leaf obviously facilitates the evaporation from the spongy parenchyma layers. Possibly other factors connected with the diseased condition may also operate to cause increased transpiration.

While not strictly parallel, it may be proper in this connection to cite results which BURGERSTEIN[3] obtained with the use of dilute solutions of camphor. He found that solutions containing about one part of camphor per thousand had an accelerating influence upon most plants investigated. Excised shoots, which were previously allowed to become somewhat wilted, revived more quickly when placed in camphor water than when placed in distilled water. By weighing the vessels of water in the two cases, it was shown that transpiration from the shoots went on more rapidly in camphor water than in distilled water. That camphor was absorbed by the excised shoots was shown by their pathological condition and death prior to the appearance of any such conditions in the parallel series in distilled water. It seems proper to regard this result as an example of transpiration under pathological conditions, since the deleterious substances thrown off by fungi may act similarly to the camphor.

Results of a somewhat similar import have been reported by one of the authors of this paper, showing that substances like tannic acid and pyrogallol when present in small amounts accelerate transpiration.[4] Small amounts of oxalic and acetic acids were likewise shown to accelerate transpiration. Since these substances are found as such in plants, it is possible that they may influence transpiration more or less independently of other factors.

The studies upon transpiration herein described were conducted

[3] BURGERSTEIN A., Über einige physiologische und pathologische Wirkungen des Kampfers auf die Pflanzen, inbesonders auf Laubesprosse. Verh. Kais. Kön. Zoolog.-Botan. Gesells. Wien **34**:543. 1884.

[4] REED. H. S., The effect of certain chemical agents upon the transpiration and growth of wheat seedlings. BOT. GAZ. **49**:81. 1910.

upon the apple varieties York Imperial and Ben Davis in orchards near Middletown, Virginia, in 1911 and 1912. All of the trees upon which studies were made were more than eight years old, and, aside from a certain amount of dwarfing due to continued attacks of cedar rust in one of the orchards, the trees were in good physiological condition.

The time available for making satisfactory studies on transpiration of the diseased leaves was restricted to a period of about five weeks beginning near the middle of July. Before that date the cedar rust had not developed sufficiently to derange seriously, or at least uniformly, the activity of the apple leaves. Subsequent to this period, the fungus has injured or even killed more or less extensive areas in the infected leaves, and, in cases of severe infection, the leaves begin falling during the latter part of August.

The work here reported was carried out on leaves and twigs on the trees in their normal position. This method was believed to be preferable, since it has been shown by FREEMAN[5] that actively transpiring shoots do not usually transpire at a normal rate when removed from their own roots.

The data reported in the present paper were obtained by inclosing a few apple leaves in a glass cylinder and absorbing the exhaled water with weighed calcium chloride. The method of carrying on the experiments will be evident from the accompanying sketch of the apparatus (fig. 1), which is a type modified from that of FREEMAN (*loc. cit.*) and others.

In its essentials the apparatus consisted of three parts: a wide mouth glass jar (*A*) which contained the twig under experimentation, a calcium chloride tube (*B*), and an aspirator (*C*) which drew a known volume of air through the apparatus. The glass jar (*A*) was fitted with a soft rubber stopper which was cut through about three-fourths of its diameter. The opposing surfaces were notched at the center of the stopper to allow a twig to pass through, but the notch was small enough to insure a tight fit and prevent the passage of air. Two perforations in the stopper allowed glass tubes of 5 mm. diameter to pass. Tube 1, through which the air entered, extended to within 1 cm. of the bottom of the jar; tube 2,

[5] FREEMAN, G. F., A method for the quantitative determination of transpiration in plants. BOT. GAZ. **46**:118. 1908.

through which air left the jar, extended only about 1 cm. inside of the stopper. Tube 2 was connected with rubber tubing to a glass-stoppered calcium chloride tube (*B*). The calcium chloride tubes were accurately weighed at the laboratory before and after each experiment. The ground stoppers (*3*, *3*), when turned, effectually closed the tubes.

The aspirator for drawing air through the apparatus was a bottle of 19 liters capacity fitted with a siphon through which the flow

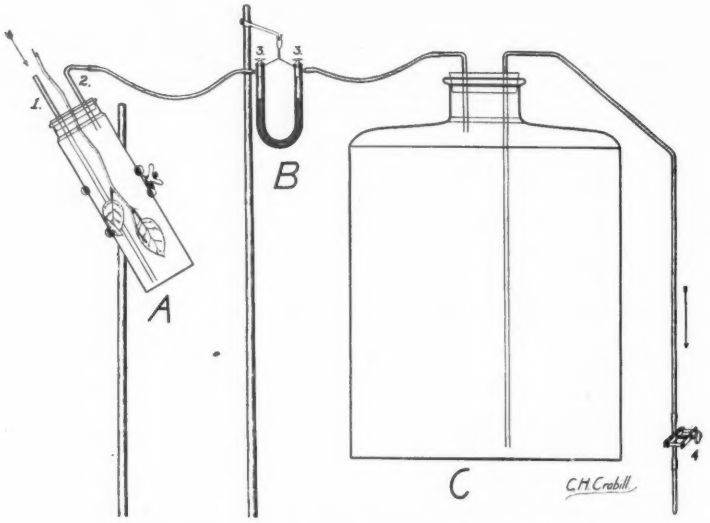

FIG. 1.—Apparatus for measuring transpiration: explained in text

could be regulated by means of a screw clamp (*4*). Three sets of apparatus were constructed and carried in a spring wagon which could be moved from tree to tree as occasion required.

The manner of conducting an experiment was as follows. The apparatus was placed at a tree where direct rays of sunlight would not strike it. A twig bearing leaves suitable for experiment was selected and inserted in the cleft rubber stopper, precautions against bruising or injuring the bark being used. In some cases one or two leaves had to be removed from the twig in order to make a good adjustment. After a few trials it was found that not more

than two apple leaves could be used in an experiment with a moderate rate of aspiration; if more were used, water would sometimes collect in the jar *A*. A thermometer was inserted in the jar with the twig, or suspended close to it. The previously weighed U-tube was connected on one side with tube 2 and on the other with the aspirator *C*, which contained 19 liters of water. Care was taken that the temperature of the water used in the aspirator should be very close to that of the air. When the siphon was started, the stoppers (*3*, *3*) were turned to allow air to flow through the apparatus. The flow of water could be regulated by means of the screw clamp (*4*) after a little experience, so that the time required to draw out 19 liters should be close to an hour.

The first apparatus was set up with healthy leaves in the jar *A;* another experiment was similarly set up with leaves infected with cedar rust; a third experiment was set up but with the omission of the jar *A*. These three, each with its own aspirator, were started as nearly simultaneously as possible, and the temperature kept uniform. The purpose of the third set of apparatus was to determine the amount of moisture in 19 liters of air.

The criticism might justly be made that the evaporating power of the atmosphere was not taken into strict account by this sort of an experiment. If the purpose had been to study the conditions or amount of transpiration, such determinations should have been made, but the purpose was to study the comparative transpiration of the healthy and diseased apple leaves, and as such it is believed to fulfil its purpose. Another possibility of error might be found in the vapor pressure from the water in *C*, which would carry back some moisture into the tube *B* and cause the results to be too large. This source of error, however, is obviated by the use of the blank, whose increase in weight was subtracted from each of the accompanying tests.

As soon as the aspirator ceased running, the glass stoppers of the U-tubes were closed and the time noted. The leaves were plucked from the twig, placed in a labeled envelope, and taken to the laboratory along with the set of U-tubes. After weighing the tubes and computing the gain in weight, the necessary correction was made for the moisture absorbed from sources other than the leaves as registered by the increase in weight of the blank.

The outline of the leaves used was carefully traced on paper and the area measured with a planimeter. The results thus obtained were computed and expressed as grams of water transpired per hour per sq. cm. A sample record sheet is herewith given, showing the records as made in the field.

TRANSPIRATION TEST NO. 2	
July 13, 1912	
Healthy York Imperial leaves	
Temperature	30.5° C.
No. of leaves in test	1
Area of leaves	21.3 sq. cm.
Vol. of air used	19 liters
Exper't began	10:18 A.M.
Exper't ended	11:20 A.M.
Duration	62 min.
Final wt. of tube	91.555 gm.
Initial wt. of tube	91.185 gm.
Difference	0.370 gm.
Water in equiv. vol. air	0.291 gm.
Water from leaves	0.079 gm.
Water per hr. per sq. cm.	0.0036 gm.

TRANSPIRATION TEST NO. 3	
July 13, 1912	
Diseased York Imperial leaves	
Temperature	30.0° C.
No. of leaves in test	1
Area of leaves	35.2 sq. cm.
Vol. of air used	19 liters
Exper't began	10:14 A.M.
Exper't ended	11:16 A.M.
Duration	62 min.
Final wt. of tube	99.675 gm.
Initial wt. of tube	99.297 gm.
Difference	0.378 gm.
Water in equiv. vol. air	0.291 gm.
Water from leaves	0.087 gm.
Water per hr. per sq. cm.	0.0023 gm.

There were 52 determinations made upon healthy and diseased leaves of the York Imperial and 26 upon leaves of the Ben Davis. The results are presented in tabular form in tables I and II.

An inspection of the tables shows that the unit transpiration of the diseased leaves of both varieties of apples was in the majority of cases less than that of the healthy, although exceptions are to be noted. Some of these discrepancies may have arisen from unguarded errors of manipulation, but it is not probable that all are due to such cause.

It is not apparent that the ratio between the transpiration in the healthy and diseased leaves was subject to any regular hourly variation. The unit transpiration in each case naturally varied from hour to hour, but the ratios were in general the same at any given period of the day.

The average ratio of transpiration in the diseased and healthy

TABLE I

TRANSPIRATION OF DISEASED AND HEALTHY YORK LEAVES

No.	Date	Hour at which experiment began	Transpiration of healthy leaves in gm. per hr. per sq. cm.	Transpiration of diseased leaves in gm. per hr. per sq. cm.	Percentage of water transpired by diseased leaves
	1912				
1	July 9	3:27 P.M.	0.00627	0.0064	103.6
2	9	4:15 P.M.	0.00257	0.00203	78.6
3	10	9:10 A.M.	0.0022	0.0033	150.0
4	10	10:20 A.M.	0.0074	0.0069	93.2
5	10	2:20 P.M.	0.0039	0.0043	110.3
6	10	3:50 P.M.	0.0041	0.0040	97.5
7	12	9:30 A.M.	0.0057	0.0065	114.0
8	12	10:45 A.M.	0.0134	0.0071	52.9
9	12	2:45 P.M.	0.0046	0.0048	104.3
10	12	4:05 P.M.	0.0079	0.0040	50.6
11	13	9:03 A.M.	0.0083	0.0106	127.7
12	13	10:14 A.M.	0.0036	0.0023	63.9
13	13	1:38 P.M.	0.00403	0.0043	106.7
14	15	9:06 A.M.	0.00508	0.0082	161.4
15	15	10:07 A.M.	0.0079	0.01033	130.7
16	16	10:20 A.M.	0.0257	0.0095	36.9
17	17	1:45 P.M.	0.0102	0.0078	76.4
18	17	3:00 P.M.	0.008	0.0022	31.4
19	17	8:17 A.M.	0.0102	0.0057	56.0
20	17	9:40 A.M.	0.143	0.0096	67.1
21	22	8:50 A.M.	0.0063	0.0028	44.4
22	22	9:50 A.M.	0.006	0.00505	84.2
23	22	1:50 P.M.	0.0101	0.00718	71.1
24	22	2:57 P.M.	0.0116	0.0088	75.1
25	23	8:38 A.M.	0.00505	0.0029	57.4
26	23	9:55 A.M.	0.00863	0.00573	66.4
27	23	2:45 P.M.	0.0104	0.00808	77.7
28	23	1:53 P.M.	0.0171	0.00589	34.4
29	25	2:35 P.M.	0.00617	0.00465	75.3
30	25	1:40 P.M.	0.0058	0.00425	73.3
31	26	9:30 A.M.	0.00908	0.0066	71.3
32	26	8:30 A.M.	0.0056	0.00439	78.4
33	26	1:35 P.M.	0.00737	0.006638	90.1
34	26	2:25 P.M.	0.00743	0.00408	54.9
35	27	9:25 A.M.	0.0105	0.0072	68.6
36	27	2:10 P.M.	0.0079	0.00606	76.7
37	Aug. 15	3:10 P.M.	0.0057	0.00335	58.8
38	15	4:30 P.M.	0.00445	0.0011	24.8
39	16	10:33 A.M.	0.00562	0.00375	66.7
40	16	2:45 P.M.	0.0055	0.0051	92.9
41	16	4:17 P.M.	0.0148	0.0107	72.3
42	17	9:40 A.M.	0.0047	0.00351	74.8
43	19	8:45 A.M.	0.00508	0.0025	49.2
44	19	3:20 P.M.	0.0055	0.0060	109.1
45	19	4:33 P.M.	0.0104	0.00706	67.9
46	20	10:54 A.M.	0.5003	0.0034	64.1
47	20	2:18 P.M.	0.002918	0.002908	99.6
48	20	3:35 P.M.	0.0036	0.00248	68.3

TABLE I—*Continued*

No.	Date	Hour at which experiment began	Transpiration of healthy leaves in gm. per hr. per sq. cm.	Transpiration of diseased leaves in gm. per hr. per sq. cm.	Percentage of water transpired by diseased leaves
	1911				
49.....	July 26	4:00 P.M.	0.0025	0.0022	88.0
50.....	27	10:03 A.M.	0.0052	0.0043	82.7
51.....	27	2:14 P.M.	0.0024	0.0019	79.2
52.....	27	3:30 P.M.	0.0029	0.0016	62.1

TABLE II

TRANSPIRATION OF HEALTHY AND DISEASED BEN DAVIS LEAVES

No.	Date	Hour at which experiment began	Transpiration of healthy leaves in gm. per hr. per sq. cm.	Transpiration of diseased leaves in gm. per hr. per sq. cm.	Percentage of water transpired by diseased leaves
	1912				
60.....	July 11	9:40 A.M.	0.0101	0.009	89.1
61.....	11	10:27 A.M.	0.0101	0.0056	55.4
62.....	11	2:24 P.M.	0.0128	0.0073	57.0
63.....	11	3:40 P.M.	0.0094	0.0048	51.0
64.....	19	9:50 A.M.	0.0065	0.0032	49.2
65.....	19	8:40 A.M.	0.0032	0.0026	81.25
66.....	19	12:49 P.M.	0.0065	0.00305	46.9
67.....	19	1:50 P.M.	0.0043	0.00406	94.4
68.....	20	9:54 A.M.	0.0041	0.0025	61.0
69.....	20	8:45 A.M.	0.0042	0.0020	47.6
70.....	20	1:50 P.M.	0.0031	0.0037	119.3
71.....	29	2:20 P.M.	0.00675	0.00597	88.4
72.....	29	3:25 P.M.	0.00913	0.0066	72.5
73.....	30	9:20 A.M.	0.0053	0.0041	77.2
74.....	30	8:20 A.M.	0.00574	0.00409	71.2
75.....	30	2:44 P.M.	0.0100	0.00442	44.2
76.....	30	2:45 P.M.	0.0061	0.0045	73.8
77.....	Aug. 22	10:44 A.M.	0.0065	0.0045	69.2
78.....	22	3:08 P.M.	0.00638	0.0042	65.8
79.....	22	4:20 P.M.	0.0028	0.0034	121.4
80.....	23	9:28 A.M.	0.0044	0.0034	77.3
	1911				
81.....	July 22	3:45 P.M.	0.00243	0.0017	68.7
82.....	24	2:46 P.M.	0.0075	0.0039	52.0
83.....	24	2:57 P.M.	0.0067	0.0023	34.3
84.....	25	11:00 A.M.	0.0039	0.0061	156.4
85.....	25	3:45 P.M.	0.0079	0.0046	58.2

leaves comes out very nearly the same in each variety of apple studied, 78.3 for the York and 74.2 for the Ben Davis.

The ratios show certain differences if they are grouped according to periods covering different stages in the development of the disease. The first, from July 1 to 15, is a stage in which the fungus is still immature. At that time none of the peridia have broken

open, although the thickened cushions are abundant. The second period, from July 17 to 31, marks a time in which the fungus has reached maturity and the leaf of the host begins to exhibit indications of serious injury. The diseased leaves at this time, owing to the expansion of the ventral surfaces by the cluster cups, are rolled toward the dorsal surface. During this second period many peridia open for the liberation of aecidiospores. The third period studied, August 15 to 23, covers a time in which the full effects of the fungus upon its host were very manifest. At that time many of the infected leaves had fallen from the trees, or, if they remained, they had a greater or less proportion of dead tissue. In table III the percentages of water transpired in these three periods are given.

TABLE III

TRANSPIRATION BY PERIODS

Percentage of water transpired by diseased leaves

Dates	York Imperial	Ben Davis
July 1–16.....	94.7	69.1
17–31.....	66.5	71.3
Aug. 15–23.....	70.7	83.4
For entire time of the experiments.....	78.3	72.4

From these figures it appears that in the first period the average unit transpiration of the diseased York leaves was nearly as great as that of the healthy leaves. In the second period the ratio dropped to 66.5, and rose to 70.7 in the third period. The ratios in the case of the Ben Davis leaves did not materially vary from the first to the second periods, but they showed considerable rise in the third period.

The rusted Ben Davis leaves used in the experiments had an average of 7.7 infections per sq. cm.; the York leaves had an average of 5.7 per sq. cm.

Part of the improvement in unit transpiration observed in August is no doubt due to the fact that the most seriously infected leaves (comparable to those used in the foregoing periods) had fallen off, and less seriously infected leaves were used as test objects.

Attention may also be directed to the problem of diminished unit transpiration of these diseased leaves and its causes. The

fungus may work in one or more ways to diminish transpiration, either by its intoxicating action upon the host cells or by causing hypertrophy which alters the normal activities of the leaves. Each of these problems is at present the subject of further investigations. Without going into a study of the cytomorphology of the diseased leaves at this time, it may be said that the portions of the apple leaves bearing cluster cups are three to four times the normal thickness. Their hypertrophy is, as REYNOLDS[6] has reported, chiefly the result of changes in the spongy tissue (parenchyma), by which the loose tissue with large intercellular spaces is replaced by large columnar cells with no intercellular spaces. Stomata are scarce or lacking and the substomatal cavities are altogether lacking. This closure of the intercellular spaces of the leaf diminishes the opportunity for water elimination from the interior of the leaf and consequently affects the transpiration. This may account for the difference between our results and those of BLODGETT previously cited. In the case of the leaves attacked by *G. interstitialis*, the destruction of the lower epidermis facilitates loss of water; while in the apple leaves attacked by *Gymnosporangium Juniperi-virginianae*, the hypertrophy obliterates the stomata and retards the elimination of water.

The retardation of transpiration in the apple leaves studied is believed to have some significance for the study of the real problems concerned with this disease. It has for a long time been known that transpiration and growth are intimately associated. Growth does not usually occur without transpiration. LIVINGSTON[7] and others have shown that in certain instances, at least, transpiration is a reliable index of growth.

Further studies are being made upon the economy of diseased trees, but it is considered that the decreased transpiration of leaves affected with the cedar rust is one factor which may account for the bad physiological condition of such trees.

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[6] REYNOLDS, E. S., Studies of parasitized leaf tissue. BOT. GAZ. **53**: 365. 1912.

[7] LIVINGSTON, B. E., Relation of transpiration to growth in wheat. BOT. GAZ. **40**: 178. 1905.

UNDESCRIBED PLANTS FROM GUATEMALA AND OTHER CENTRAL AMERICAN REPUBLICS XXXVI[1]

JOHN DONNELL SMITH

Rheedia paniculata Donn. Sm.—Folia coriacea orbiculari-obovata basi attenuata remote crasseque penninervia, nervis transversalibus venisque immersis. Flores paniculati, pedicellis singulis. Ovarium 5-loculare.

Ramuli terminales digitum crassi foveolis mutue applicatis apiculati cicatricibus foliorum obovatis 8 mm. longis notati, internodiis 2–3 cm. longis. Folia solum superiora visa 19–24 cm. longa 15–19 cm. lata apice rotundata in siccis concoloria pallide lutescentia nervis fuscentia, nervo mediano supra complanato subtus triangulari, nervis lateralibus ab eo sub angulo fere recto abeuntibus utrinque 11–12 inter se 15–22 mm. distantibus subrectis pone marginem evanescentibus, petiolis 3–4 cm. longis canaliculatis basi incrassata amplexicaulibus in axilla foveola valde prominente ovali 9 mm. longa appendiculatis. Paniculae ad cicatricem foliorum 2–4nae-pedunculo 1.5–3.5 cm. longo computato 4–6 cm. longae 1–3-plo trichotomae, axibus quadrangularibus, ramis 4 decussatis, pedicellis 6 mm. longis medio bibracteolatis, bracteolis semi-orbicularibus 1 mm. longis. Sepala obtuse ovata 2 mm. longa. Petala concava oblongo-elliptica 4.5–5.5 mm. longa uti sepala sub anthesi reflexa. Stamina sub disco inserta usque ad 51, filamentis 3 mm. longis. Ovarium ovoideum 5-sulcatum, stylo brevissimo, stigmate 5-lobo. Bacca ignota.

Inter rivulos *Unión* et *Del Convento* dictos in valle Diquís, Comarca de Puntarenas, Costa Rica, alt. 800, Febr. 1898, *H. Pittier* n. 11957.

Caryocar costaricense Donn. Sm.—Folia oblongo-elliptica obtuse acuminata basi acuta vel obtusa subintegra subtus nervis barbata. Stipellae majores ovatae tenuiter acuminatae concavae basi saccatae, minores orbiculares cucullatae. Racemus pubescens, pedicellis suberectis, prophyllis obsoletis.

Arbor vasta ex schedula Pittieriana, ramulis teretibus sicut petioli petioluli pedunculi pedicelli strigilloso-pubescentibus, internodiis 4.5–7 cm. longis. Foliola terna 10–13.5 cm. longa 4.5–7 cm. lata pergamentacea supra glabra venulis pellucida obscure repanda, nervis lateralibus utrinque 10–12, petiolo communi 5–8.5 cm. longo, petiolulis purpurascentibus 3–4 mm. longis. Stipellae 4 persistentes, 2 majoribus 5 mm. longis ceterao dimidio minores

[1] Continued from BOT. GAZ. **54**:235. 1912.

involucrantibus. Pedunculus 9.5 cm. longus 5 mm. crassus, racemo corymbiformi floribus exemptis 5 cm. longo, rhachi 3 cm. longa, pedicellis circiter 15 robustis 3–4 cm. longis, floribus glabris allium olentibus (cl. repertor in scheda). Calyx 4.5 mm. altus 5.5 mm. latus, basi incrassata explanata, lobis semiorbicularibus 3 mm. longis. Petala 5 obovato-oblonga 18–21 mm. longa lutea margine scariosa integra. Stamina 1.5–2 cm. longa, filamentis totis ob glandulas quasi monilliformibus, antheris ellipticis aegre 1 mm. longis. Ovarium 4-loculare, stylis 11 mm. longis. Drupa ignota.—*C. glabro* Pers. proximum.—Ab incolis *Ajo* (Latine *Allium*) vocatur.

Río del Volcán, in valle Diquís, Comarca de Puntarenas, Costa Rica, alt. 250 m., Febr. 1898, *H. Pittier* n. 12115.

Maytenus enantiophyllus Donn. Sm.—Folia opposita ovato-lanceolata crenato-serrulata. Cymae longe pedunculatae semel bisve trichotomae, axibus capillaribus, floribus tetrameris. Ovarium 4-loculare, ovulis geminis superpositis, stylo brevissimo, stigmate subintegro. Capsula 2–3-locularis loculicida, seminibus singulis.

Arbor 7-metralis omnibus in partibus glabra, ramulis subtetragonis. Folia pergamentacea opaca subtus glandulis sanguineis passim punctata 8–11 cm. longa 2.5–3.5 cm. lata elongato-acuminata apice ipso obtusa basi acutiuscula, crenis glandula apiculatis, petiolo 4–7 mm. longo. Pedunculi gracillimi 2–3.5 cm. longi, cymis plerumque semel furcatis, axibus 6–12 mm. longis, bracteis lineari-lanceolatis 2 mm. longis uti bracteolae minutae sanguineis. Sepala semiorbicularia 1 mm. longa. Petala orbiculari-obovata 4 mm. longa. Stamina ad marginem disci inserta, filamentis e basi glandulari-incrassata subulatis 1 mm. longis recurvis, antheris globosis 0.5 mm.-diametralibus. Discus planus subquadratus 2.5 mm.-diametralis. Ovarium ovoideum 1.5 mm. longum nonnunquam rudimentarium, stylo 0.5 mm. longo, stigmate obscure 4-lobulato. Capsula carnosa virescens subglobosa 1 cm.-diametralis, valvis ultra medium loculicidis, seminibus totis arillo inclusis ellipsoideis 8 mm. longis, testa membranacea coccinea, albumine carnoso.—Species *Mygindam* revocans foliis oppositis anormalis.

Chiul, Depart. Quiché, Guatemala, alt. 2500 m., Apr. 1892, *Heyde et Lux* n. 3087 ex Pl. Guat. etc. quas ed. Donn. Sm.

Meliosma (§ SIMPLICES Warburg) **Tonduzii** Donn. Sm.—Folia oblanceolata 3–3.5-plo longiora quam latiora cuspidato-acuminata in petiolum attenuata integra vel denticulata. Flores singuli pedicellati. Petala exteriora parum inaequalia leviter imbricata calyptratim decidua. Discus obsoletus. Drupa pyriformis obsolete marginata prope basin latere altero tumida.

Arbor symmetrica ex repertore, ramis ramulisque teretiusculis glabris, gemmis ferrugineo-pilosiusculis. Folia coriacea nitida, juniora 13–18 cm. longa 4–5.5 cm. lata integra, provectiora usque ad 32 cm. longa 9 cm. lata superne minute remoteque denticulata, costa cum nervis lateralibus utrinque 15–17 supra impressa subtus crassiuscule prominente, petiolis glabris 2–3.5 cm. longis basi incrassatis. Paniculae ferrugineo-appressoque-pubescentes 13 cm. longae, ramis primariis 2 inferioribus divaricatis 4.5–7 cm. longis, ceteris sicut secundarii brevissimis, bracteis linearibus 2 mm. longis, pedicellis 1 mm. longis, bracteolis semiorbicularibus imbricatis pubescentibus. Sepala suborbicularia 1 mm. longa herbacea ciliolata basi pubescentia. Petala coriacea orbicularia 3 mm.-diametralia concava glabra, interiora linearia 2 mm. longa glabra staminodiis semiadnata. Ovarium ovoideum 1 mm. longum biloculare, loculis biovulatis, stylo ovarium bis superante suboblique inserto sursum decrescente, stigmate punctiformi. Drupa pedicello 3–6 mm. longo oblique insidens nitida in sicco nigra 24 mm. longa superne 18 mm. lata prope basin 9 mm. lata ad 7 mm. supra basin foveolata et ibidem saepe styli reliquum ferente, endocarpio osseo basi transversim intrusa subbidentata seminifero.—*M. glabratae* Urb. proxima.

In silvis ad Vueltas, Tucurrique, Costa Rica, alt. 650 m., Maj. 1899, *Adolfo Tonduz* n. 13368.—In silvis prope ostium fluminis *Zhorquín* dicti, Talamanca, Costa Rica, Mart. 1894, *Adolfo Tonduz* n. 8584.

Phyllocarpus septentrionalis Donn. Sm.—Foliola 4–6-juga majuscula elliptica utrinque acuta vel obtusinscula coriacea nitida. Sepala ampla ciliolata, inferioribus ellipticis, summo orbiculari. Vagina staminalis valde obliqua filamentis brevior, antheris parum aequalibus.

Arbor excelsa, ramulis petiolis racemis pubescentibus. Foliola plerumque 5-juga praeter costam et marginem subtus pubescentes glabra per paria deorsum decrescentia, supremis usque ad 8 cm. longis 3.5 cm. latis, infimis circiter 3 cm. longis 2 cm. latis, petiolo communi 1–3.5 cm. longo, stipulis linearibus 7 mm. longis deciduis, rhachi 8–12 cm. longa, petiolulis 1 mm. longis incrassatis. Racemi ad nodos defoliatos 1–4-ni subsessiles, rhachi 10–13 mm. longa, pedicellis 4–7-nis 11–15 mm. longis prope basin articulatis et ibidem bracteolis 2 connatis lanceolatis 2 mm. longis instructis, floribus praeter calycem glabris. Sepala cartilaginea 9–11 mm. longa. Petala tenuiter membranacea, lateralibus summo intimo bis fere majoribus, inferioribus minimis vel deficientibus. Vagina staminalis postice 12 mm. longa antice 9 mm. longa, filamentis 14–17 mm. longis, decimo summo libero 18 mm. longo, antheris 2–2.5 mm. longis. Ovarium lineari-oblongum 5 mm. longum circiter 3-ovulatum, stylo 13 mm. longo, stigmate globoso. Legumen indehiscens 1–2-spermum, dispermum dum adsit usque ad 17 cm. longum 4.5 cm. latum, monospermum 12.5 cm. longum 4 cm. latum, suturae ala 10–12 mm. lata. Semen ovale 2.5 cm. longum 1.5 cm.

latum, radicula recta 2.5 mm. longa.—Haec ab specie hactenus unica hemisphaerii meridionalis Americani incola differt inter alia foliolis paucioribus et uti flores majoribus.

Prope Gualán, Depart. Zacapa, Guatemala, alt. 100 m., Febr. 1912, *Wilmatte P. Cockerell;* exemplum tantum floriferum in herbario Musei Nationalis sub numero proprio 1861342 servatur. De hac specie ita in literis scribit cl. repertor, domina oculatissima res novas acute cernens: Arbor usque ad 18–25-metralis ad ripas Río Montagua et secus viam ferream haud rara floribus praecocibus coccineis odoratis speciosissima formicis apibus volucribus frequentissima ab incolis *Guacomaya* vocata.—Exempla foliifera et fructifera eodem loco Maj. 1912 legit *E. Morris.*

Calyptrella cycliophylla Donn. Sm.—Folia suborbicularia deltoideo-cuspidata basi obtusa quinquenervia coriacea subtus glandulis punctulata. Flores breviter pedicellati ebracteolati hexameri. Calyx furfuraceus. Petala lanceolata attenuato-producta breviter unguiculata. Capsula nitida subovoidea 4–5-valvis.

Ramuli fistulosi subtetragoni cum petiolis et panicula ferruginei furfuracei vel glabrescentes. Folia glabra 19–22 cm. longa 15–17 cm. lata, cuspide 5 mm. longa obtusa, nervis transversis 6–12 mm. inter se distantibus, petiolo teretiusculo 6–8 cm. longo. Panicula deltoidea pedunculo 8 cm. longo praetermisso 21 cm. longa, axibus sicut pedunculus tetragonis sulcatis, ramis inferioribus quaternariis, pedicellis 3–7-nis 1–2 mm. longis cum calyce dense griseo-furfuraceis, flofibus inapertis lanceolato-ovoideis 5.5 mm. longis, calyptra glabra apice nutante. Calyx subhemisphaericus 2 mm. altus 3 mm. latus 12-costatus. Petala 6 inaequalia 5 mm. longa satis asymmetrica late unguiculata obscure 6-nervia. Stamina 12, antheris 1.5–2 mm. longis filamenta subaequantibus. Ovarium calycem haud superans nitidum sulcatum, stylo 3.5 mm. longo recto. Capsula nigra calyce bis longior 5 mm. longa 3 mm. crassa 4–5-angularis et-sulcata, valvis plerumque 4, seminibus filiformibus 2 mm. longis straminiis.

Secus rivulum prope Buenos Aires, Comarca de Puntarenas, Costa Rica, alt. 280 m., Jan. 1892, *Ad. Tonduz* n. 4964.—Ad ripas fluminis *La Unión* dicti, Comarca de Puntarenas, Costa Rica, Jan. 1897, *H. Pittier* n. 10584.

Gilibertia gonatopoda Donn. Sm.—Folia maxima elliptica obtuse cuspidata basi acuta vel obtusiuscula. Racemi terminales vel laterales, pedunculis crassis sulcatis paulo infra medium pluribracteolatis articulatis geniculatis ceterum nudis. Calyx turbinatus petalis longior. Drupa globosa.

Arbor mediocris, ramulis subteretibus sulcatis. Folia pergamentacea 11–30 cm. longa 5–18 cm. lata integra, nervis lateralibus utrinsecus 9–10 subrectis

in utraque pagina conspicuis, petiolis canaliculatis sulcatis 2–12 cm. longis, stipulis deciduis. Racemi floriferi rhachis 4–5 cm. longa, pedunculi 8–16 circiter 2.5–3.5 cm. longi epidermate transversim rimulosi ad articulationem nodosam bracteolis 4–6 rotundatis 1 mm. altis circumdati, receptaculum parce minuteque bracteolatum, pedicelli 25–40 circiter 8–11 mm. longi, flores pentameri 4.5–5 mm. longi. Calyx 2.5–3 mm. longus 2 mm. latus margine subinteger. Petala subcarnosa ovata 2 mm. longa acuta 1-nervia staminibus subaequilonga. Discus hemisphaericus 1.5 mm.-diametralis. Styli in conum 0.5 mm. altum toti connati. Drupae optime globosae 4 mm.-diametrales columna stylari 1 mm. longa disci dimidium aequante coronatae.

Ad ripas fluminis *Turrialba* dicti, Prov. Cartago, Costa Rica, alt. 500 m., Mart. 1894, *John Donnell Smith* n. 4829 ex Pl. Guat. etc. quas ed. Donn. Sm. —In silvis prope flumen *Zhorquín* dictum, Talamanca, Costa Rica, alt. 200 m., Mart. 1894, *A. Tonduz* n. 8512.—In silvis ad Shirores, Talamanca, Costa Rica, alt. 100 m., Febr. 1895, *A. Tonduz* n. 9323.—In silvis apud Tsaki, Talamanca, Costa Rica, alt. 200 m., Apr. 1895, *A. Tonduz* n. 9587.—Ad marginem fluminis *Del Convento* dicti, in valle Diquís, Comarca de Puntarenas, Costa Rica, Mart. 1898, *H. Pittier* n. 12110. Secus fluvium *Las Vueltas* dictum, Tucurrique, Costa Rica, alt. 635 m., Jan. 1899, *A. Tonduz* n. 12962.

Gilibertia stenocarpa Donn. Sm.—Folia alia indivisa oblongo-ovata vel-elliptica, alia ad medium fere trilobata, lobo terminali rotundato cuspidato, lateralibus acuminatis. Umbellae racemosae, pedicellis flores vix aequantibus. Drupa elliptica triente longior quam latior.

Arbor 10–15-metralis. Folia membranacea subtus glandulis rubellis punctulata margine integra circumscriptione quam maxime variabilia, nempe: indivisa 12–16 cm. longa 6–11 cm. lata acuminata basi cuneata utrinque 6–7-penninervia, folia lobata cum praecedentibus intermixta ambitu rhomboidea suborbicularia vel transversim ovalia 11–17 cm. longa 8–20 cm. lata triplinervia, lobo terminali maximo 6–9.5 cm. longo 4–7 cm. lato dimidio superiore plerumque semiorbiculari, lateralibus subtriangularibus vel acuminato-ovatis 2–6.5 cm. longis atque latis, altero insolenter obsoleto. Petioli 5–22 cm. longi. Stipulae minimae rubiginoso-pubescentes. Inflorescentia terminalis. Racemi floriferi rhachis juvenilis rubiginoso-pubescens, adulta 4 cm. longa, pedunculi 16–21 circiter 2 cm. longi parce dissite minuteque bracteolati, receptaculi bracteolae rubiginoso-pubescentes, pedicelli 2.5–3 mm. longi, floreres usque ad 45 pentameri 3.5 mm. longi. Calyx obpyramidalis 1.5 mm. altus atque latus minute denticulatus. Petala ovata 1.5 mm. longa scariosa staminibus paulo superata. Styli in conum 1 mm. fere altum disci dimidium aequantem toti connati. Drupae 6 mm. longae 4 mm. crassae columna stylari 2 mm. fere longa coronatae.

In praeruptis *Barranca de Eminencia* dictis, Depart. Amatitlán, Guatemala, alt. 1200 m., Febr. 1892, *John Donnell Smith* n. 2666 ex Pl. Guat. etc. quas ed. Donn. Sm.—Santa Rosa, Depart. Santa Rosa, Guatemala, alt. 1300 m., Maj. 1892, *Heyde et Lux* n. 3348 ex Pl. Guat. etc. quas ed. Donn. Sm.—El Salvador, loco accuratius haud addicto, *Carlos Rénson* n. 66 (Exemplum in herb. Musei Nationalis numero proprio 576040 signatum vidi.)

Gilibertiae species in America Centrali obviae ad inflorescentiam ceteris characteribus neglectis dignosci possunt, nempe:

I. Umbella solitaria. *G. querceti* Donn. Sm. (*Dendropanax querceti* Donn. Sm.)
II. Umbellae racemosae.
  A. Pedunculi medio articulati. *G. gonatopoda* Donn. Sm.
  B. Pedunculi inarticulati.
    1. Pedicelli flores vix aequantes. *G. stenocarpa* Donn. Sm.
    2. Pedicelli flores superantes.
      a. Umbellae 25–40-florae. *G. arborea* E. March.
      b. Umbellae 10–20-florae. *G. Rothschuhii* Harms.

Basanacantha (?) **grandifolia** Donn. Sm.—Inermis. Folia coriacea permaxima lanceolato-vel elliptico-oblonga utrinque acuta. Stipulae numerosissime imbricatae scariosae minimae in bracteas transientes. Flores masculini pluri-aggregati subsessiles, calyce bracteis imbricatis fere velato breviter dentato.

Tota stipulis praetermissis glabra. Ramuli teretes. Folia tantum suprema obvia bina 28–32 cm. longa 9–14.5 cm. lata saepius falcata utrinque nitida subtus elevato-punctulata, nervis lateralibus utrinsecus 10–12 arcuatim anastomosantibus, petiolo canaliculato 2.5–3.5 cm. longo. Stipulae apicem interpetiolarem ramulorum obtegentes leviter cohaerentes ferrugineae late ovatae 4 mm. longae mucrone nigro cuspidatae extus punctulatae intus elongato-glandulosae et cano-villosae. Flores solum masculini visi subcapitulati, pedicellis crassis 1.5 mm. longis. Calyx campanulatus 3 mm. longus, dentibus subulatis 1 mm. longis margine scarioso connexis. Corolla hypocraterimorpha, tubo 5-sulcato 12 mm. longo, lobis acuminato-ovatis 7 mm. longis. Antherae inclusae subsessiles lineares 5 mm. longae apice obtusae basi retusae paulo infra medium affixae. Discus elevato-pulvinaris 1.5 mm. altus 2 mm. latus centro intrusus. Ovarii rudimentum nullum, stylo 11 mm. longo triente bifido. Bacca ignota.—Species habitu stipulisque insignis et fortasse melius genus proprium censenda.

In silvis prope Santo Domingo, Golfo Dulce, Comarca de Puntarenas, Costa Rica, Febr. 1896, *Adolfo Tonduz* n. 9878.—Ad ripas fluminis *Corozal* dicti, prope Santo Domingo, Golfo Dulce, Costa Rica, Apr. 1896, *Adolfo Tonduz* n. 9982.

Perymenium ruacophilum Donn. Sm.—Folia lanceolato-ovata basi acuta trinervia serrulata supra scabridiuscula subtus glabrescentia. Corymbi remote patenterque ramosi, pedicellis trinis. Involucri bracteae 3–seriatae oblongae obtusae superne fimbrillatae. Receptaculum conicum.

Rami cum ramulis remotissimis brachiatis teretiusculi sulcati glabri purpurascentes, gemmis axillaribus cano-pilosis. Folia membranacea 6.5–9 cm. longa 2–5 cm. lata tenuiter acuminata e basi ipsa trinervia calloso-serrulata, petiolis 1.5–2.5 cm. longis pubescentibus linea pubescente connexis. Corymbi glabrescentes inferne foliis reductis ceterum bracteolis linearibus 2–5 mm. longis pubescentibus instructi, eorum bene evolutorum rhachi 2.5 cm. longa, ramis inferioribus 2.5 cm. longis, pedicellis circiter 1.5 cm. longis dissite et saepe sub capitulo bracteolatis. Capitula oblongo-obovata 10–11 mm. longa, involucri bracteis apice purpurascentibus margine membranaceo lacerato minute fimbrillatis, intimis 6 mm. longis, extimis 3 mm. longis, receptaculo 2 mm. alto atque lato, paleis flores parum amplectantibus 6–7 mm. longis acuminatis minute ciliolatis. Ligulae 6–7 circiter 9–10 mm. longae 2–3-denticulatae. Flores disci numerosi 8 mm. longi. Achenia compresso-triquetra 2 mm. longa glabra deorsum angustiora basi callosa, maturis calvis, pappi aristis numerosis distinctis ciliolatis caducissimis.

In monte *Volcán Santa Maria* dicto, Depart. Quezaltenango, Guatemala, alt. 2500–3500 m., Jan. 1896, *E. W. Nelson* n. 3727.

Arctostaphylos (§ EUARCTOSTAPHYLOS Drude.) **cratericola** Donn. Sm.—(*A. pungens* H.B. et K., var. *cratericola* Donn. Sm. in BOT. GAZ. **15**:13. 1891.)—Folia glabra obovata vel obovato-elliptica calloso-apiculata subtus punctulata. Racemi puberuli, pedicellis flore 2–3-plo brevioribus. Filamenta nuda corolla 3-plo breviora antheris bis longiora, aristis antherae aequilongis.

Fruticulus coespitosus, caulibus prostratis 3–4 dm. longis ramosis dense foliatis fuscis cortice exfoliantibus, ramulis apice trigonis puberulis ceterum glabris. Folia 14–20 mm. longa 9–10 mm. lata leviter induplicativa minute reticulata rosaceo-apiculata passim rosaceo-maculata, juniora margine puberula, petiolis 2–3 mm. longis puberulis. Racemi subsessiles nutantes subcapituliformes 6–8-flori erubescentes, pedicellis 2–3 mm. longis, bractea exteriore lineari-lanceolata 5 mm. longa. Calycis segmenta suborbiculata 2 mm. longa ciliolata rosacea. Corolla urceolata, tubo 6 mm. longo albido, dentibus semiorbiculatis 1 mm. longis reflexis rosaceis. Filamenta 2 mm. longa infra medium suborbiculari-dilatata. Discus 10-sulcatus. Ovarium 5-loculare stylo addito corollae tubum fere aequans. Drupa ignota.

Ad rupes in cratere, Volcán de Agua, Depart. Zacatepéquez, Guatemala,

alt. 3600 m., Apr. 1890, *John Donnell Smith* n. 2159 ex Pl. Guat. etc. quas ed Donn. Sm.—Volcán de Agua, Depart. Zacatepéquez, Guatemala, alt. 2700–3100 m., Febr. 1905, *W. A. Kellerman* nn. 4754, 4950.

Cordia gualanensis Donn. Sm.—Folia inter minima ex ovali ovata vel oblongo-ovata cuspidata integra supra scabrida subtus strigillosa. Cymae terminales folia subaequantes. Calyx esulcatus, dentibus 5 subulatis brevibus. Corolla infundibularis, tubo quam calyx bis quam lobi dimidio longiore. Stamina 4–8.

Frutex ut videtur, ramis teretibus glabris. Folia 18–31 mm. longa 12–18 mm. lata, nervis lateralibus utrinque 6–7 uti venae transversales subparallelae inter se 1–2 mm. distantes et costa fuscentibus, petiolis 1–4 mm. longis. Cymae nondum satis evolutae solum visae terminales et ad apicem ramulorum brevissimorum foliis juvenilibus instructorum pseudo-axillares fusco-velutinae 9–12-florae, pedunculo 2–3-mm. longo, rhachi 10–13 mm. longa. Calyx subsessilis campanulatus extus fulvo-sericeus intus puberulus 5-costatus minute reticulatus, tubo 5 mm. longo, dentibus 1 mm. longis. Corollae puberulae tubus, 11–12 mm. longus, lobi 4–8 obovati 7 mm. longi. Stamina usque ad medium fere corollae tubum et subaequaliter affixa saepe inaequilonga, antheris inclusis vel breviter exsertis cordiformibus 1.5 mm. longis retroversis. Ovarium pyramidale 2 mm. longum glabrum, stylo 7 mm. longo triente bifido, ramis dimidio bifidis, stigmatibus clavatis. Drupa deficiens.

Gualán, Depart. Zacapa, Guatemala, alt. 122 m., Mart. 1905, *W. A. Kellerman* n. 5105. (Exemplum in herb. Musei Nationalis numero proprio 576295 signatum exstat.)

BALTIMORE, MARYLAND

VEGETATIVE REPRODUCTION IN AN EPHEDRA

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 172

W. J. G. LAND

(WITH FIVE FIGURES)

When the branches of many plants are covered with soil or even make contact with it, they may put out roots and produce new plants. This method of reproduction is common among angiosperms and to a less degree among gymnosperms, where heretofore it has been reported only for Coniferales. Many species, distributed among *Abies*, *Picea*, *Pinus*, *Larix*, *Pseudotsuga*, *Thuja*, *Chamaecyparis*, and *Cryptomeria*, produce new plants by the rooting of horizontal branches which then either erect the tip of the rooting branch or send out erect lateral shoots. The unfortunate term "layering" has been applied to this method of vegetative reproduction.

The latest account for a gymnosperm is that of COOPER[1], who describes "layering" in *Abies balsamea* and cites the scanty literature of the subject.

Until now no special method of vegetative reproduction has been reported for Gnetales, perhaps because the relative inaccessibility of the group has prevented careful field studies.

In September 1911 occasional clumps of an *Ephedra* were found on the very steep rocky sides of the cañon of Rifle Creek, near the southern boundary of the White River forest reserve in western Colorado. This *Ephedra* is probably conspecific with *E. nevadensis*, although differing from the latter in some minor characters.

Rifle Creek, where it falls over the edge of the White River plateau, for some miles has carved out of very hard limestone a box cañon with walls in some places rising perpendicularly to a height of more than 150 meters (fig. 1), or even leaning outward over the cañon floor. Emerging from the box cañon the stream flows for

[1] COOPER, WILLIAM S., Reproduction by layering among conifers. BOT. GAZ. 52:369–379. *fig. 1.* 1911.

a short distance through soft limestone with regular slopes steeply V-shaped, then through sandstone conglomerate, which being very friable weathers rapidly. The faces of the sandstone slopes show a series of low cliffs (fig. 2) alternating with nearly bare talus. The walls of the cañon are exceedingly unstable.

Ephedra is sparsely distributed along the cañon walls for nearly four miles, occurring only on the most exposed and most unstable slopes in clumps of from four or five plants to sometimes twenty

FIG. 1.—Limestone cliff at entrance to the box cañon of Rifle Creek, near the upper limit of *Ephedra*, which is found in small quantities at the top and in the talus slope at the base.

or infrequently more. Isolated plants are rare and an examination of one of these showed that it had been torn from a clump on a cliff above by a small landslide. The vertical range is as sharply limited as is the horizontal, no plants being found at an altitude below 2000 nor above 2200 meters. The clusters are most abundant on the sandstone slopes, the greatest display and most vigorous plants being near the lower limiting altitude (fig. 2); thence running up the ridges between the small side cañons and becoming

fewer and fewer until they completely disappear at 2200 meters. Rarely plants are found growing in the scanty bowlder-strewn soil on ledges along the face of the limestone walls of the box cañon. In one instance a small clump was seen on the extreme edge of the great cliff (fig. 1) which towers above the cañon floor. In the coarse limestone talus at its base were a few plants, much battered by falling stones. This cliff, rising almost to the vertical range of *Ephedra* is capped by a steep ridge of the coarse friable sand-

FIG. 2.—*Ephedra* on sandstone talus near lower limiting altitude; dead *Pinus edulis* in foreground; a typical situation.

stone of the lower cañon. Here also were a few small clumps of depauperate plants. *Ephedra* was not found on the relatively moist, well-wooded north slopes nor in the cañons of adjacent watercourses, but the rough nature of the country made extended search somewhat difficult.

Some plants reach a height of 2.5 meters, and below the first branching, which is usually at the surface of the soil, may attain a diameter of 10 cm. The largest trunk found (fig. 3) had a diameter of 5 cm. just above the first fork. The greatest number of seasonal

rings found was 40, showing that the plant is comparatively short-lived.

Associated with *Ephedra* are occasional plants of *Artemisia tridentata*, the older ones much battered by snowslides and rolling stones, and quantities of *Cercocarpus parvifolius*, the mountain mahogany. Rarely indeed in the sandstone talus a plant of *Equisetum* is found. On more stable slopes *Pinus edulis* and species of *Juniperus* are fairly abundant. The general instability of the

FIG. 3.—An old *Ephedra* on a comparatively stable slope; the oldest plant found in the region, having 40 growth rings.

region is well shown in fig. 2, where a pine has perished because of the rapid wearing away of the sandstone cliff.

A careful and persistent search throughout the range of *Ephedra* was made for seedlings, but since none could be found, it seemed evident that such a short-lived plant, in order to maintain itself under the severe conditions imposed by its habitat, must have some method of vegetative reproduction. The almost universal occurrence of clumps led to a careful examination of the underground condition. In nearly every instance it was found that the

individuals of a group are either actually connected by means of underground stems or that traces of a former connection could be made out. Sections show that these underground connections are stems and not roots.

Large boulders and masses of friable rocks are continually being detached from the cañon walls, and these, together with deep accumulations of snow, are sufficient to overthrow even the largest plants of *Ephedra*, as is shown in fig. 4. At the right, in this figure,

FIG. 4.—A clump of *Ephedra* showing large plants being overthrown by boulders

two boulders are bending down one of the largest plants of the clump. The branches of this plant will finally be forced into contact with the soil, most likely be covered with talus, take root, and give rise to a new cluster of plants. An almost completely decayed trunk was found under the boulder shown at the extreme left of the figure. This trunk had given rise to a small clump not shown. Young plants are so slender that they are easily overthrown and buried by small landslides. On a loose and rapidly moving slope composed of small stones and coarse sand, underground connections were traced for 5 meters. The oldest plant showing five

seasonal rings was above and the younger ones farther down the slope, stretched out in an almost straight line by the flowing talus. After a stem has been buried it is sometimes difficult to detect the growth of succeeding seasons.

Underground stems rising from stems which have been buried for some years were found creeping among the loose stones and coarse sand of the sandstone slopes. These shoots are, in effect, rhizomes which later produce aerial shoots either by branching or by erecting

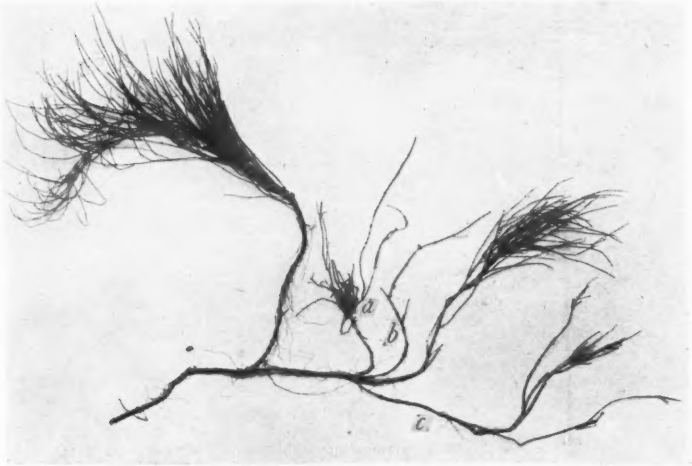

FIG. 5.—Underground connections of a small clump of *Ephedra* found in the talus shown at the extreme right of fig. 2; *a*, young rhizome; *b*, older rhizome which has sent up an aerial shoot; *c*, rhizomes which have erected their stem tips.

the main stem tip, or by both methods. The rhizome habit is shown in fig. 5. The branched underground shoot *a*, springing from the buried stem which has also given rise to the damaged cluster of aerial branches, has grown in one season (1911). At *b* is an older stem which has produced an aerial branch. At *c* is a stem which has branched, and the branches, after a time, have become aerial by erecting their tips. The rhizomatous branches were not found where the soil is compact, being only in loose sand and small stones. It seems worthy of note that the soil above 2200 meters, the upper

limiting altitude of *Ephedra*, is compact. Since the tendency of soil movement is to force the plant constantly toward lower altitudes, if it were not for underground lateral branching, *Ephedra* would first be driven from the higher slopes and ultimately from the region.

If *Ephedra* does produce seeds in this region they are promptly destroyed by small animals. Not many seedlings of pine and spruce are found, although great quantities of seeds mature. Spruce seeds are eaten by squirrels as soon as they ripen and long before they fall. Great numbers of piñon jays visit the region in autumn and feed on the nuts of *Pinus edulis*. However, piñons and spruces are so abundant that enough seeds to keep up the forest are overlooked. It is regretted that observations cannot soon be made to determine if *Ephedra* really does set seed in this region.

Most of the branches of this *Ephedra* fall at the close of summer, a regular abscis layer being developed at each node. In September the ground under the plants is green with the fallen branches.

Ephedra nevadensis was found in western Colorado only on the most bleak and unstable slopes and does not seem to be widely distributed. No seedlings were found. The plant propagates itself vegetatively by shoots, which, after having been overthrown and buried by talus, take root, erect their tips, and send out erect lateral branches; and also by means of underground rhizomes which are given off from older buried shoots. These rhizomes either send up branches or erect their tips or they may do both. They may also send out other rhizomes. Assuming the absence of seeds, *Ephedra* owes its preservation in this region to the rhizome-forming habit. If it were not for this habit and if other factors which are not apparent at present did not intervene, soil movement would ultimately force the plant below the lower limiting altitude and cause it to disappear entirely from the region.

University of Chicago

PROTOPLASMIC CONTRACTIONS RESEMBLING PLASMOLYSIS WHICH ARE CAUSED BY PURE DISTILLED WATER

W. J. V. Osterhout

(WITH SIX FIGURES)

True plasmolysis is produced only by solutions which are hypertonic, but appearances almost or quite indistinguishable from it may be brought about by hypotonic solutions.[1] Some light is thrown on the nature of this result by a study of certain cases in which it is caused by pure distilled water.[2]

Material for such study is afforded by marine plants. The root tips of the eel-grass (*Zostera marina*) are well adapted to this purpose. The roots were carefully removed from the sand in which they were growing and immediately placed in sea water. Some of the younger roots (which had not yet become brown at the end) were selected. About an inch of the root tip was removed and placed on a hollow-ground slide in such a way that the young root hairs did not come into contact with the glass. The root tip was covered with sea water and examined without a cover glass (by means of an 8 mm. objective and an ocular magnifying ten times). Root tips which were shown by such examination to be normal in appearance were fastened by means of vaseline to cover glasses which were then attached to irrigation chambers of the form shown in fig. 1. Care was taken to prevent the young root hairs from touching the glass or the vaseline.

The arrangement of the apparatus may be understood from figs. 1 and 2. The irrigation chamber consists of an ordinary

[1] Cf. Bot. Gaz. **46**:53. 1908.

[2] Water twice distilled from glass is usually regarded as pure, especially when the first and last thirds of the distillate are rejected, but such water may be toxic to plants as long as any part of the apparatus is new. The water used in these experiments was prepared with due regard to these facts. In place of stoppers, plugs of absorbent cotton were used; contamination by spattering was prevented by baffling plates of glass and glass wool. The water so obtained was not toxic to such test objects as sensitive species of *Spirogyra* and the root hairs of *Gypsophila*.

glass slide with a circular opening (15 mm. in diameter) into which is fitted a glass cylinder (*c*) 12 mm. high upon which is cemented a glass disc (*d*); surrounding this is another cylinder, the width of the space between the two being about 1 mm.; a part of this space is filled with paraffin (*e*). The outer cylinder is pierced on both sides by small glass tubes (*b*, *b*). The outer cylinder projects above the inner so that when the cover glass (*f*) is in place the width of the space between (*d*) and (*f*) is a little less than 1 mm. It is necessary to have this space narrow, since otherwise when introducing a solution of greater specific gravity than the one with which the chamber is filled, the new solution may flow over the bottom of the space without coming into contact with the plants, which are fastened to the under side of the cover glass. The paraffin (*e*) extends downward to the slide; the liquid is in consequence obliged to pass upward through the space between (*d*) and (*f*) before it can flow out at the opposite side, and it must therefore bathe the plants which are attached to the cover glass (*f*).

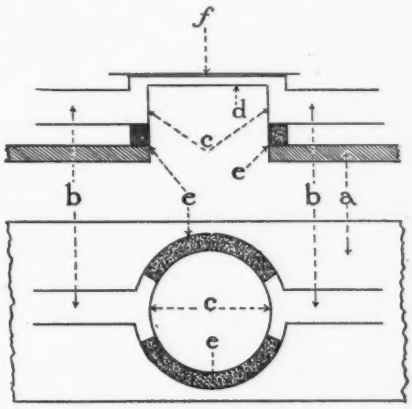

FIG. 1.—Sectional views of irrigation chamber: *a*, slide; *b*, inlet and outlet tubes; *c*, glass cylinder; *d*, glass plate; *f*, cover glass (upper line) and material (lower line).

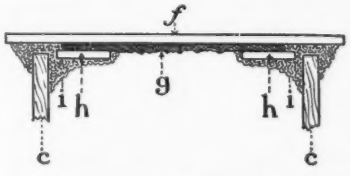

FIG. 2.—Material in irrigation chamber: *c*, glass cylinder; *f*, cover glass; *g*, material; *h*, bits of cover glass; *i*, vaseline. —Sectional view.

The attachment is made in the manner shown in fig. 2. The plant is first fastened to the cover glass (*f*) by vaseline (*i*, indicated by the dotted area) and a drop

of sea water is placed on it; bits of cover glass (*h*, *h*) are then thickly covered with vaseline, and pressed down upon it to hold it in place. The outer cylinder is smeared with vaseline and sea water is then poured into a funnel which is connected by a rubber tube with the inlet tube (*b*); as soon as all the air has been expelled from this tube and the chamber is so full of sea water that the surface of the liquid is decidedly convex, the cover glass (with the attached root tip) is inverted and pressed down upon the outer cylinder in the manner shown in the figure. Care should be taken during the subsequent irrigation not to admit air to the inlet tube.

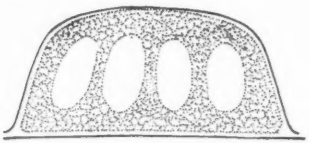

FIG. 3

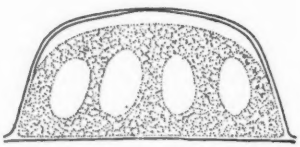

FIG. 4

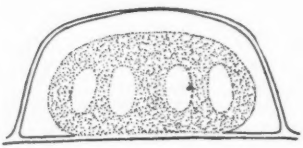

FIG. 5

FIGS. 3–5.—Optical section of young root hair cell of *Zostera marina* (diagrammatic); fig. 4, the cell shown in fig. 3 after treatment with distilled water (diagrammatic); fig. 5, the cell shown in fig. 4 after more prolonged treatment with distilled water (diagrammatic).

After being placed in the chamber, the root tips were irrigated for a time with sea water while camera lucida sketches were made of root hairs in various stages of development. Each of the cells which had been sketched was than kept under observation during the subsequent irrigation with distilled water. Root tips which were irrigated with sea water throughout the experiment served as controls.

The application of distilled water causes a contraction of the protoplasm which often closely resembles the true plasmolysis produced by hypertonic sea water (which has been concentrated by evaporation) or by hypertonic sugar solutions. Figs. 4 and 5 show the appearance of such cells. The mode and the degree

of contraction vary somewhat, but in general the variations in true plasmolysis are of the same sort as in what may be conveniently called the false plasmolysis. We may use the term "false plasmolysis" to designate not only the contraction produced by distilled water but also that which is caused by hypotonic solutions.

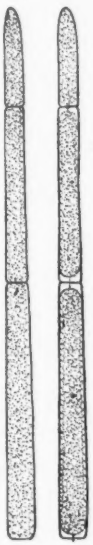

FIG. 6.—Surface view of the end of a hair of *Polysiphonia violacea:* at the left in natural condition; at the right after treatment for two minutes with distilled water (diagrammatic).

The contraction may take place rather slowly, in many cases requiring half an hour or more to reach the stage shown in fig. 4. True plasmolysis may take place much more rapidly. But this distinction does not hold generally, for in many cases contractions which closely simulate true plasmolysis may take place with great rapidity. To give a single example of this, the behavior of the colorless terminal cells and of hairs of *Polysiphonia violacea*[3] may be described. On being irrigated with distilled water these cells contract very rapidly, so that at the end of two minutes they reach the stage shown at the right in fig. 6, in which they are practically indistinguishable from cells plasmolyzed by hypertonic sea water or hypertonic sugar solutions. The older cells reach the same stage more slowly and betray by the alteration of their chromatophores that they are undergoing false plasmolysis. It should be noted that by applying hypertonic solutions of many salts, both true and false plasmolysis may be produced simultaneously. These contractions are (as a rule) irreversible, at least as soon as they have passed a certain stage.

The effects which have been described as due to distilled water were also produced by water taken directly from ponds, rivers, and springs; they are not due, therefore, to toxic substances resulting from the process of distillation; this point is emphasized because attention has previously been drawn to the

[3] Kindly identified by Dr. W. G. FARLOW.

fact that water distilled in a metal still produces such results in *Spirogyra*, while pure distilled water does not.

The cause of these effects lies in an increase in the permeability of the plasma membrane (and likewise of internal cell membranes), as the result of which some or all of the substances which maintain the osmotic pressure of the cell diffuse out; the protoplasm then shrinks as the result of loss of water from the vacuoles, which in consequence become smaller, as is shown in figs. 3–5. This is often followed by an apparent "coagulation" of the protoplasm, which is sometimes evidenced by the assumption of an irregular outline. Most of the characteristic features of cytolysis as described for animal cells are lacking. In some cases, however (particularly in cells which are not surrounded by a cell wall), they occur.

These effects might naturally be ascribed to the absorption of water by the protoplasm, but they cannot be due to this cause, for observation shows that the cells do not increase in size as they would if water were absorbed. In some cases a few of the cells burst when transferred to distilled water, but the majority do not burst or even swell noticeably. This is probably due in some cases to the fact that swelling is prevented by the cell wall, for some cells which lack the cell wall (for example, spores of *Polysiphonia*) may swell in distilled water. Moreover, it was found that isotonic solutions of cane sugar produce the same effects as distilled water although not as rapidly.

The increased permeability must be due, therefore, to the loss of certain substances upon which the maintenance of the normal permeability depends. The most important of these are undoubtedly the inorganic salts. If the concentration of salts be lowered beyond a certain point, the permeability of the membrane increases very rapidly. This is shown by experiments in which the increase of permeability is directly measured by electrical means. In sea water plus an equal amount of distilled water the cells do not shrink, but with the addition of three volumes of distilled water they may begin to shrink in seven hours or less, and with increasing amount of distilled water shrinkage takes place more and more rapidly. These remarks apply only to balanced solutions such as sea water.

The effect of unbalanced solutions on permeability has been discussed elsewhere.[4]

The facts described above have an important bearing on certain theories recently advocated by some biologists and colloid chemists. According to these authors, the effects which are usually attributed to osmotic pressure are in reality due to imbibition or to the giving up of water by the protoplasm, without the intervention of a semipermeable membrane. It would not be possible on this theory to account for the shrinkage of the protoplasm of a cell to half its volume when transferred from sea water to distilled water, especially when the process is irreversible. But the explanation given above—the increase of permeability of a semipermeable membrane—not only agrees with the facts described here, but also with those derived from a variety of other material, and by the use of entirely different methods.

LABORATORY OF PLANT PHYSIOLOGY
HARVARD UNIVERSITY

[4] Science, N.S. **35**:112. 1912; **36**:350. 1912.

REPRODUCTION BY LAYERING IN THE BLACK SPRUCE

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 173

GEORGE D. FULLER

(WITH SIX FIGURES)

During the summer of 1912, while making some ecological studies along the Saguenay River, Quebec, attention was directed

FIG. 1.—The black spruce growing on granite with a basal whorl of prostrate branches; Chicoutimi County, Quebec.

to the process of forest development upon granitic areas with very little soil, where the rocky surface was exposed to the full sweep of the wind. The most careful studies were made on a series of

granite hills with typical *roches moutonnées* contours and with elevations varying from 100 to 200 meters, in Chicoutimi County, bordering an arm of the river known as Ha! Ha! Bay. In these exposed situations there occurred a characteristic pioneer forest association consisting, as far as its tree species were concerned, of black spruce (*Picea mariana* Mill. BSP.), Jack pine (*Pinus Banksiana* Lamb.), the white birch (*Betula alba papyrifera* (March.) Spach.), and the aspen (*Populus tremuloides* Michx.), together with occasional trees

FIG. 2.—The prostrate branches of the black spruce rooting in the mat of mosses and lichens and producing upright shoots; one such shoot has been provided with a white background.

of a few other species. Because of the slow weathering of these areas, the pioneer stages of forestation were much prolonged, but appeared to be promoted by the development of a peculiar growth habit and a resulting vegetative reproduction by layering. This habit was most highly developed and occurred most frequently in the black spruce.

Grown in swamps or thickets the black spruce is characterized by a narrow irregular cone of branches. This cone was found to be

even more slender in the sparse stand upon the granite surfaces, but in these open situations there were in addition to the short branches on the upper part of the trunk longer ones near the surface of the rock (figs. 1 and 2), forming a compact mat, none of the twigs more than half a meter high. At least one-half of the total foliage of the trees was usually upon these prostrate branches, and it would seem from the apparent vigor of the leaves that an even larger proportion of the work of food synthesis was to

FIG. 3.—A dead stump of black spruce with a circle of living offspring from its layered branches.

be referred to this lower stratum. The rooting of the trees in these rocky habitats was, as a rule, very shallow, and hence the massing of their branches reduced the exposure to winds and the consequent danger of uprooting. The habit was necessarily confined to open stands.

The mat of lichens and mosses which antedated the tree continued to thrive under and among the prostrate branches and the resulting soil soon buried portions of the lower members of the mass. On *Pinus Banksiana* this was apparently without results other than

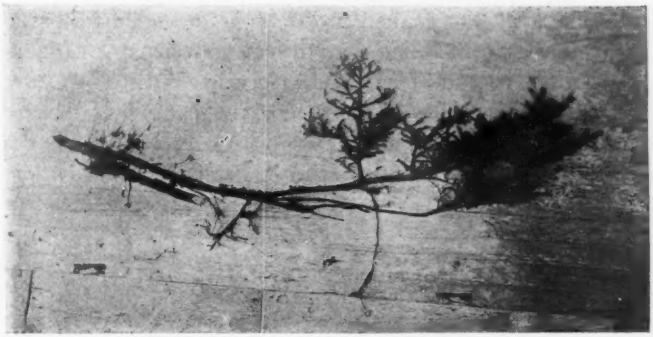

FIG. 4.—A rooted branch of black spruce the result of layering; the upright shoot is the one with the white background in fig. 2.

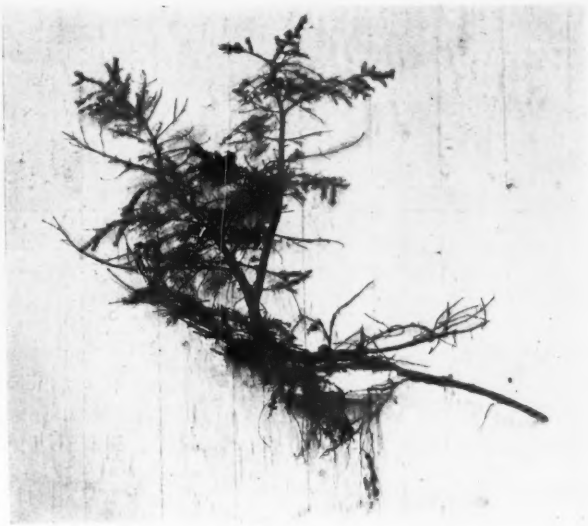

FIG. 5.—A layered branch of black spruce

somewhat more securely anchoring the trees, but on the spruces it often stimulated the production of roots from the buried branches and caused a circle of young trees to surround the parent (fig. 2).

Such reproduction in conifers was recently discussed by COOPER,[1] who also gave very complete citations of the scanty literature of the subject. The layering habit in *Picea mariana* has been mentioned by LOUDON,[2] for specimens growing under partial cultivation on the British Isles, but its importance in increasing the stand upon

FIG. 6.—A group of young black spruce descended by layering from a single parent tree; the remains of the dead parent are concealed by the young trees; Chicoutimi County, Quebec.

rocky areas seems to have escaped notice. The fact that the rate of growth has been found to be very slow in such localities[3] makes such a method of rapid multiplication and replacement an even greater advantage to the species possessing it. Should trees

[1] COOPER, W. S., Reproduction by layering among conifers. BOT. GAZ. **52**:369–379. 1911.

[2] LOUDON, J. C., Arboretum et Fruticetum Britannicum. London. 1844.

[3] COOPER, W. S., The climax forest of Isle Royale, Lake Superior, and its development. II. BOT. GAZ. **55**:115–140. 1913.

of the black spruce growing on granite be cut down, their early replacement is much more definitely assured (fig. 3).

By this layering circular areas with a radius of 2–4 meters soon become covered with vigorous young upright shoots, like the one provided with a white background in fig. 2, which is 2.4 meters from the main trunk. This shoot was removed from the soil and proved to be one of two upon a prostrate branch rooted at several points throughout its length (fig. 4). The orthotropic development of the shoot is well marked, while several other twigs showed it in a less marked degree. The development of such shoots seems to be closely connected with the production of adventitious roots, although not always dependent upon it. Occasionally an abundance of adventitious roots was unaccompanied by any definitely orthotropic shoots (fig. 5). This was frequently noticed in the layering of *Abies balsamea* as it occurs in its shrubby habit in the deeper forests.

The layering was seldom found on *Picea canadensis*, because this species rarely occurs in exposed rocky situations as a member of the pioneer forest association. By far the greatest importance of the habit, in the Saguenay region, is its abundance in the black spruce. Often large clumps of small trees could be referred to the parentage of a few individuals, although with increase in size the connections became increasingly difficult to trace. Frequently clusters of 6–20 closely clustered young trees (fig. 6) marked the spot where a tree of a former generation stood, showing much more rapid replacement than could have been effected by seed.

UNIVERSITY OF CHICAGO

BRIEFER ARTICLES

THOMAS HOWELL

(WITH PORTRAIT)

Mr. THOMAS HOWELL, the pioneer botanist of Oregon, died on December 3, 1912, in Portland, at the age of 70 years. He was born near Pisgah, Missouri, October 9, 1842, whence he moved to Oregon in 1850, before railroads had entered the state. Although he received a meager school education, he was a well learned man and an enthusiastic botanist. He did not marry until his 54th year. His wife and a son of seven survive him.

Just before his death he completed the second edition of his *Flora of Northwestern America*, replacing the BENTHAM and HOOKER system with that of ENGLER and PRANTL. This publication embodies the life work of Mr. HOWELL, who spent more than 30 years tramping and traveling over the states of Washington and Oregon. Considering the vast area of these states, and the vicissitudes of pioneer life in that far isolated country, the task of accumulating the data for such a complete flora of the region is realized. Naming the localities worked in these states would require much space; suffice it to say, that the only places he did not visit were portions of central northern Washington and of the central part of Oregon. It is not known to the writer how much material he collected; the Field Museum alone has 2263 specimens. His flora lists and describes about 3290 species. It was the good fortune of Mr. HOWELL to discover and describe the last of the Pacific coast conifers, *Picea Breweriana*, the weeping spruce, a very local tree near the Oregon-California line, which he first found at Waldo, in the Siskiyou Mountains, at an elevation of 6000 feet.

Mr. HOWELL was materially unfortunate in having lived in a region where his knowledge of systematic botany yielded him no financial remuneration, save from the limited sale of his book. His love of study and enjoyment of the vastness of the Pacific Northwest he considered ample reward. The sad part of his later life was his limited finances. For the last several years he was compelled to live in a poor foreign section of Portland, eking out a frugal existence in a small grocery-confectionery store, which also served as his residence. When visited last by the writer, he was making coarse teamsters mittens on a sewing

machine for seven cents a pair. Under such conditions was his book revised. Mr. HOWELL, however, was very cheerful at all times and betrayed no impatience with depressing external conditions.

According to his own statement, the picture here produced is the only one ever taken of him. It represents him seated at his typewriter with the first copy of his revised flora. Behind him are seen stacks of completed mittens. It was made by the writer during a visit, October 14, 1910.—HURON H. SMITH, *Field Museum of Natural History, Chicago.*

THE SEEDLING OF PHYLLOCARPUS

(WITH ONE FIGURE)

When recently collecting insects at Gualan, Guatemala, Mrs. COCKERELL was so fortunate as to discover a new species of *Phyllocarpus*, a genus previously known from a single species found in Brazil. It is a large tree, with magnificent red flowers, much visited by insects. The circumstances attending the discovery have been related at some length in the *Canadian Entomologist* (September 1912, pp. 278, 279). Seeds were later obtained by Mr. E. MORRIS, and we were successful in getting some of them to germinate. I described the seedling in an early stage, before the fleshy cotyledons had appeared, and was away from home during the development of the later stages. From the accompanying figures it will be seen that the seedling is essentially like that of *Caesalpinia*. At the stage represented by the figures, the following characters are apparent:

FIG. 1.—Seedling of *Phyllocarpus*, n. sp.: from Gualan, Guatemala, by W. P. COCKERELL; apical leaflet not expanded.

Epicotylar stalk strongly pubescent, with spreading fine hairs as long as half its diameter, and more abundant short curled ones; petioles the same, only more hairy; first leaves 7-foliolate; leaflets light pea green, rather broad lanceolate, quite entire, nearly sessile, but inequilateral at base; perfectly glabrous except the margins, which are densely white-hairy, and the midribs beneath, which are hairy like the petioles.—T. D. A. COCKERELL, *University of Colorado, Boulder.*

CURRENT LITERATURE

MINOR NOTICES

A new color guide.—A new color guide by Dr. ROBERT RIDGWAY,[1] the well known ornithologist, is practically an entirely revised and much enlarged edition of his earlier nomenclature of colors (1886) with 17 plates and 186 colors as against 53 plates and 1115 colors in the present work. The color work was done by A. Hoen & Co., Baltimore, and is much more uniform in different copies than in the earlier edition, which was hand-stenciled from several mixings of the same color; while in the present work each color for the whole edition of 5000 copies was prepared from one lot of color and uniformly coated at one time.

The work is designed to be equally useful to botanists, florists, artists, dyers, merchants, and chemists who require a standard color scheme. The colors have evidently been standardized to a degree of accuracy not hitherto attained in any color chart. The colors are one-half by one inch, arranged on a heavy gray paper in three vertical columns of 7 colors each. All the colors are named as well as symbolized, but if a given color comes between "hermosa pink" (1 *f*) and "eosine pink" (1 *d*), it could be designated 1 *e*. In this manner about 2385 additional colors or a total of 3500 can be designated. Undoubtedly exception will be taken to some of the names, but in this the personal equation plays such a large part that decisions must be rather arbitrarily rendered. The primary colors have been standardized by Dr. P. G. NUTTING of the U.S. Bureau of Standards.

A table of percentages of color, together with an explanation of the amount of white, black, or neutral gray used as above, will give an approximately ready clue to the reproduction of any color in the guide, the only uncertain factor being the possible lack of standardized primary colors to begin with. Definitions of the principal color terms, such as color, shade, tint, hue, tone, etc., which are used almost interchangeably by many people, will repay careful study by those not familiar with their exact use.

A slight error on p. 12, due to a misunderstanding, should be corrected. Mr. F. A. WALPOLE had no connection with the color project of the American Mycological Society, the preparation of which was delegated to the late Dr. L. M. UNDERWOOD, Dr. W. A. MURRILL, and the writer. MR. WALPOLE died before the committee was appointed, and the project was abandoned after two years' work by the committee in favor of Dr. RIDGWAY'S work which had not previously come to their notice.—P. L. RICKER.

[1] RIDGWAY, ROBERT, Color standards and color nomenclature. pp. 44. *pls. 53*. Published by the author (3447 Oakwood Terrace N.W., Washington, D.C.). 1912. $8.00.

Homologizing plants and insects.—In attempting to homologize the various parts of plants and insects, JANET[2] has succeeded in proposing several additions to our already overloaded vocabulary. The sporangium of *Marchantia* contains "isogynospores" and "isoandrospores," while that of *Selaginella* contains "macrogynospores" and "macroandrospores." The vocabulary consists mostly of words like these, which are easily understood but unnecessary and not at all likely to become a permanent part of our burden. The plant ("orthophyte") consists of a gametophyte, beginning with the spore and ending with the "gynogametes" and "androgametes," and a sporophyte, beginning with the zygote and probably including the rest of the life history, although the table gives the sporangium (called the "gynosporangium" and "androsporangium" in *Selaginella*, and the nucellus and pollen sac in spermatophytes) as the final member of this generation.

The insect is an "orthozoite," consisting of a "gametozoite" and a "sporozoite" generation. The gametozoite generation begins with a generative cell (cellule génitale) which produce "gonads," gametangia, and finally "gynogametes" and "androgametes." The sporozoite generation begins with the fertilized or parthenogenetic egg, and includes the rest of the life history.

Several years ago the reviewer tried to show[3] that, in animals as in plants, generations are characterized by the haploid and diploid number of chromosomes. JANET's paper is based upon current knowledge rather than upon any new evidence. However, we agree with him, or rather he agrees with us, that there is an alternation of generations in animals.—CHARLES J. CHAMBERLAIN.

Flora of New Guinea.—Another volume of the botanical results of the Dutch scientific expedition to New Guinea (1907 and 1909) under the auspices of Dr. H. A. LORENTZ has now appeared.[4] The first part of the botanical report was reviewed in this journal.[5] The collaborators are as follows: S. H. KOORDERS, L. RADLKOFER, A. PULLE, J. VALCKENIER SURINGAR, E. ROSENSTOCK, MAX FLEISCHER, TH. VALETON, J. J. SMITH, A. ENGLER and K. KRAUSE, C. LAUTERBACH, J. PERKINS, and L. DIELS, 72 families and 292 genera being represented, including 599 species, 153 of which are new. Three new genera are published as follows: *Capitularia* (Cyperaceae), *Gjellerupia* (Opiliaceae), and *Nouhuysia* (Guttiferae). Most of the families are introduced merely to

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[2] JANET, CHARLES, Le sporophyte et le gamétophyte du végétal; le soma et le germen de l'insecte. 8vo. pp. 65. Limoges: Ducourtieux et Goût. 1912.

[3] CHAMBERLAIN, CHARLES J., Alternation of generations in animals, from a botanical standpoint. BOT. GAZ. **39**:137–144. 1905.

[4] Nova Guinea. Résultats de l'expedition scientifique Néerlandaise à la Nouvelle-Guinée, en 1907 et 1909, sous les auspices du Dr. H. A. LORENTZ. Vol. VIII. Botanique. Livraison IV. 4to. pp. 613–898. *pls. 113–159*. Leide: E. J. Brill. 1912. Fr. 27. 50.

[5] BOT. GAZ. **49**:464. 1910.

include some additional species, but the Cyperaceae (19 genera and 97 species, 6 of which are new), Rubiaceae (16 genera and 36 species, 11 of which are new), and Filices (39 genera and 86 species, 18 of which are new) are presented with a measure of completeness. Aside from these families, the largest additions of new species are to Ericaceae (14), Euphorbiaceae (12), and Musci (10).—J. M. C.

Paleobotanical literature.—The third volume of JONGMAN'S *Die palaeobotanische Literatur* has appeared,[6] including the bibliography of 1910 and 1911. The great usefulness of this publication needs no explanation, and now that paleobotany has come to be an essential part of the morphology of vascular plants, it will serve a much larger group of botanists than the title once would have indicated. The list of authors (40 pp.) includes 374 names, representing 762 titles. The list of literature is admirably organized, so that almost any clue can be followed to the literature of a subject.—J. M. C.

NOTES FOR STUDENTS

The mucors.—Prominent among recent publications on the Mucoraceae are two papers by HAGEM[7] which deal with the distribution, taxonomy, and physiology of the soil-inhabiting mucors occurring in the vicinity of Christiania, Norway. A systematic search has revealed the presence in the soil of an unsuspected wealth and variety of these organisms, strangely in contrast with the rarity of their spores in the atmosphere. In the first paper, which deals with taxonomy and distribution, 20 species are described. Of these, 16, including 7 new species, were isolated from cultivated and forest soils. Most of these were isolated many times and some were present in remarkable abundance. Among the most frequently encountered species, *Mucor racemosus*, *M. hiemalis*, and *M. nodosus* are abundant in cultivated lands; *M. Romannianus* is most frequent in coniferous forests (50,000 spores per gram of soil), but *M. strictus*, *M. flavus*, and *M. sylvaticus* are also common. Some forms like *M. racemosus*, *M. hiemalis*, *Absidia Orchidis*, and *Zygorynchus Moelleri* are widely distributed both in cultivation and in forest soils. As showing the rarity of the spores of mucors in the air, only 8 species were isolated by means of Petri dishes containing culture media, and exposed for periods of 1–2 hours both in town and country.

The second paper deals chiefly with problems of nutrition. A large number of compounds were tested with respect to their availability as sources of

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[6] JONGMANS, W. J., Die palaeobotanische Literatur. Bibliographische Übersicht über die Arbeiten aus dem Gebiete der Palaeobotanik. Dritter Band. Die Erscheinungen der Jahre 1910 und 1911 und Nachträge für 1909. pp. 569. Jena: Gustav Fischer. 1913. *M* 26.

[7] HAGEM, O., Untersuchungen über norwegische Mucorineen. I. Vidensk. Selsk. Skrift. no. 7. pp. 50. *figs.* 22. 1907; *ibid.* II. no. 4. pp. 152. 1910.

nitrogen and of carbon for the mucors. The mass of detail is too great and too diverse to permit of recapitulation; the main features of the results, however, may be briefly summarized. The 23 mucors studied fall into two clearly separated groups with respect to their ability to assimilate nitrogen from nitrates and nitrites. In relation to these compounds it is interesting to note that all forms which were capable of assimilating nitrates were also capable of assimilating nitrites. As with other plants, the nitrates are reduced to nitrites and these to ammonia in the process of assimilation. All forms grew well when nitrogen was supplied in the form of ammonium salts. On urea, 18 species thrived, but *Mucor Romannianus* failed. In cultures with urea, ammonium carbonate is formed. Acetamide is not utilized. Uric acid is only slightly soluble, but gives good growth. The amino-acids have little nutrient value when they are the sole source of both carbon and nitrogen. When carbon is supplied in the form of glucose, the amino-acids, especially leucine and tyrosine, are utilized as a source of nitrogen by many of the soil mucors. In all cases ammonia accumulates in the culture medium. Of the non-nitrogenous carbon compounds, mannite and glycerin are not used when ammonium sulphate is the only source of nitrogen; with potassium nitrate, however, these polyatomic alcohols are assimilated by 3 or 4 species. With the exception of maltose, the disaccharides are not used except in a few cases. Six species grew well on saccharose, but of these only two showed the accumulation of reducing sugar in the culture fluid. The species which thrive on saccharose are unable to utilize that sugar when amino-acids serve as the only source of nitrogen. In explanation the author suggests that the action of the invertase of the fungi is inhibited by the presence of ammonia split off from the amino-acids. Starch in general seems not to be utilized, a fact which is all the more interesting since the conversion of starch into glucose by some species of *Rhizopus* is the basis of a commercial process. Few species grow on inulin and pectin, but some on xylan and cellulose. Of the glucosides, helicin and salicin were tried. Helicin proved valueless, while a number of mucors were capable of utilizing salicin, but only to a limited extent because of the toxic properties of the decomposition products formed.

These results on the whole seem to indicate that most of the common substances which reach the soil from the plant are only poorly suited for the nutrition of a group constituting, according to these investigations with the exception of the bacteria, one of the most abundantly represented classes of soil-organisms. It would be an interesting problem to determine to what extent the nutrition of soil mucors is dependent upon decomposition of plant products brought about by bacteria and other soil organisms.

In a third paper,[8] which forms the conclusion of HAGEM's investigations of Norwegian mucors, the author gives critical notes on their nutrition. *Mucor*

[8] HAGEM, O., Neue Untersuchungen über norwegische Mucorineen. Ann. Myc. **8**:265–286. *figs.* 11. 1910.

saturninus, *M. christianiensis*, *M. dispersus*, and *M. corticolus* are described as new in this paper. *M. norwegicus* Hagem, which was described as new in the first paper, is here regarded as a synonym of *M.* (*Rhizopus*) *nodosus* (Namyslowski) Hagem.

NAMYSLOWSKI[9] describes a new species of *Zygorynchus* isolated from the soil. This species, like the other species of the genus (*Z. Moellerii* and *Z. heterogamus*), is monoecious.

In another paper,[10] NAMYSLOWSKI has reported a long series of experiments in which, after the fashion of KLEBS, he attempts to determine the influence of various food substances in different concentration on the production of zygospores and sporangia by the mucors. The data do not allow of either general or precise conclusions, but show that the kind and concentration of nutrients have a not very well defined influence in determining the relative abundance of zygospores and sporangia. The work further brings out the fact that the distinction between monoecious and dioecious species is not always sharp, for some of the monoecious forms, like *Zygorynchus*, produce zygospores along the line of contact between two adjoining colonies, and some dioecious species show a tendency to form zygospores on mycelia derived from single spores. In one case, *Absidia glauca*, the author even succeeded in isolating a monoecious race from a species which is usually considered to be dioecious.

A number of short papers by different authors treat of the formation of zygospores and of nuclear phenomena in the mucors. LENDNER[11] has examined the method of origin of the zygospore in a number of mucors representing both monoecious and dioecious species. His observations go to show that the gametangia originate at points where two branches of the mycelium accidentally come into contact, and not, as is usually stated, on branches which grow toward each other as the result of some sort of a stimulus. MOREAU,[12] who has studied nuclear phenomena in the hyphae and zygospores of several mucors, reports that the divisions in the hyphae and gametangia are normally mitotic and simultaneous. In the columella of *Rhizopus* amitotic divisions, which

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[9] NAMYSLOWSKI, B., *Zygorynchus Vuilleminii*, une nouvelle mucorinée isolée du sol et cultivée. Ann. Myc. **8**:153–155. *figs. 9.* 1910.

[10] NAMYSLOWSKI, B., Studien über Mucorineen. Bull. Intern. Acad. Sci. Cracovie. Ser. B. 1910:577–519. *figs. 2.*

[11] LENDNER, A., Observationes sur les zygospores des Mucorinées. Bull. Soc. Bot. Genève. II. **2**:56–59. *figs. 4.* 1910.

[12] MOREAU, F., Première note sur les Mucorinées, le noyau au repos.—Le noyau en division: mitose et amitose. Bull. Soc. Mycol. France **27**:204–210. *figs. 12.* 1911.

———, Deuxième note sur les Mucorinées.—Fusions de noyaux et dégénérescence nucléaire dans la zygospore.—Fusions de noyaux sans signification sexuelle. *Ibid.* 334–341. *figs. 4.*

———, Les phénomènes internes de la reproduction sexuelle chez quelques Mucorinées hétérogames. Bull. Soc. Bot. France **58**:618–623. *figs. 4.* 1911.

apparently indicated degeneration, were observed. In the zygospores he finds that multiple fusion with degeneration of the supernumerary nuclei takes place. The fusion is preceded by a division. *Zygorynchus* offers a variation from other forms in the fewness of the nuclei which fuse (4 in one species) and in the tardiness of the fusion.

The process of zygospore formation in *Zygorynchus*, according to GRUBER,[13] shows some peculiarities which have not been observed in mucors heretofore. The zygospore arises at the point of contact between the terminal portion of an erect hypha and a lateral branch arising from the same hypha or rarely from a different hypha. At the point of contact the gametangia grow out from each hypha. Only the female gametangium is cut off by a wall at its base from the parent cell. Later a partly formed wall arises midway between the base and apex in the female gametangium, but this wall is rarely completed and soon disappears. The male gametangium remains in connection with the parent hypha. After the fusion of the gametangium a differentiated portion of the protoplasm of the male gametangium passes into the female gametangium, carrying with it 20–30 nuclei. The fusion of nuclei was not observed on account of their minuteness. The author believes that a multiple fusion takes place and that subsequently the fused nuclei divide to give the large number subsequently found in the zygote. He does not note the reduction in number observed by MOREAU. The resemblance of the manner of formation of the zygospore in this form to that of oospores suggests that *Zygorynchus*, which in other characteristics corresponds with the mucors, is akin to the oomycetes.—H. HASSELBRING.

Cecidology.—A very interesting and valuable contribution is a study of a citrus tree cecidium caused by *Sphaeropsis tumefaciens* Hedges by HEDGES and TENNY.[14] The organism was first isolated from lime tree knots from Jamaica in 1904. The knots vary in size from ⅜ to 3 inches, and are usually more or less spherical; they are light in color and smooth when young but become black and furrowed with age. The interior of the knot is hard and compact, while the outer part is soft and crumbling in character. They are frequently more or less covered with typical witches-broom growths. They occur on both old and young growths and at any season of the year, and eventually cause the death of the plant. The mycelium may grow in any tissue, but is confined to the intercellular spaces, but unfortunately the authors have not given a discussion of the structural characters of the malformations. The fungus penetrates the wood for considerable distances beyond the point of inoculation, thus making pruning an unsatisfactory treatment. Pycnidia

[13] GRUBER, E., Einige Beobachtungen über den Befruchtungsvergang bei *Zygorynchus Moelleri* Vuill. Ber. Deutsch. Bot. Gesells. **30**:126–133. *pl. 1.* 1912.

[14] HEDGES, FLORENCE, and TENNY, L. S., A knot of citrus trees caused by *Sphaeropsis tumefaciens*. Bull. no. 247. U.S. Dept. Agric. Bur. Pl. Industry. 1912.

may or may not be produced; spermogonia are produced, but perithecia and conidia have not been observed.

Another important contribution to our knowledge of American cecidology comes from COSENS,[15] of the University of Toronto. After a brief review of our present knowledge of cecidology, he discusses the results of his own investigations. The subdivisions are arranged with reference to the insects causing the galls, but the discussions are primarily botanical in character. The results of these studies confirm much of our previous knowledge and make valuable additions. The *Eriophyes* galls show a well defined series from simple indentations to well developed pouches, and from modifications of epidermis only to the palisade and mesophyll also. The modifications are those of degree rather than of kind. In the hemipterous galls the stimulation is from one side and is disseminated equally in all directions. The lepidopterous galls are characterized as a simple type. The glands are larger than in the normal tissues. The dipterous galls are extremely variable in degree of complexity and the glands are very abundant. The sawfly galls of the Hymenoptera show a great proliferation of tissue, with but very little differentiation. Tannin was especially abundant in the epidermis and bast and probably serves for the protection of the larvae. Other members of this order produce the most highly developed galls with very complicated structures. Probably the most vital part of this paper is the series of physiochemical experiments with the larvae, in which the author found that the larvae "secrete an enzyme, capable of changing starch to sugar, which acts on the starchy constituents of the nutritive zone and accelerates the rate of their change to sugar. The material thus prepared supplies nourishment for both the larva and the gall. The protoplasm of the latter is thus rendered unusually active, since it receives an abnormal quantity of available food material in a limited area. The hypertrophy and cell proliferation and probably also the appearance of vestigial tissue or other primary characters are the response of the protoplasm of the host to the additional food supply." The author also says that it is not necessary in all cases for the stimulus to be applied to the cambium, but that it may be applied to any actively growing tissue; that this stimulus acts on tissues at considerable distance from the point of application; that certain inquilines have the power of gall production to some extent.

A very brief paper on pistillody by LEWIS[16] shows the necessity for botanists to give more attention to the recording of the abnormal structures in plants. In this case both the anther and the filament were inflated and bore ovules, the anther being modified into a sessile leaflike structure with a stigmatose edge.

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[15] COSENS, A., A contribution to the morphology and biology of insect galls. Trans. Canadian Inst. **11**:297–387. *pls. 13.* 1912.

[16] LEWIS, I. W., Pistillody in *Argemone platyceras* Link and Otto. Torreya **12**:85–88. 1912.

Among the important foreign papers which are of some interest to botanists are the following: Two systematic papers by HOUARD[17] in which the author gives descriptions and notes based on the characters of the galls. Docters VAN LEEUWEN-REIJNVAAN[18] continue their very valuable descriptions of the galls of Java, describing 99 species. These descriptions are purely botanical and in most cases the species is not named, but is placed in such genus or family as may be indicated by the external characters of the cecidium. This is therefore merely the record and description of certain types of cecidia found on certain species of plants and becomes an important starting-point for future workers.—MEL T. COOK.

Motile isogametes in the Chytridiales.—KUSANO[19] has demonstrated in *Olpidium Viciae*, a new species parasitic on *Vicia unijuga*, that the free swimming zoospores sometimes conjugate much as in the lower green algae. Similar copulation was reported many years ago by FISCH in *Reesia*, which is closely related to *Olpidium*, but his account has not been generally accepted. KUSANO, however, not only followed the zygote to infection, but traced its cytological history through to the next generation of zoospores. Conjugation, which seems to occur only during the amoeboid intervals between active swarming, appears to be induced by a contact stimulus. There is a slight physiological differentiation among the zoospores in that not all of those which come together appear to have a sexual affinity, although one of such a mismated pair may often fuse with a third which comes into contact with them. Zoospores from old sporangia which have been prevented from discharging by lack of water copulate more freely than those which have recently matured. Conjugated or unconjugated zoospores may infect the host, one giving rise to resting spores, the other to zoosporangia. After encysting on the outside of the host, the young parasite penetrates the cell wall and escapes into the cell, where it is freely carried around by the rotation of the host cytoplasm, until it finally comes to rest near the nucleus. Though naked until nearly mature, it never undergoes amoeboid deformation as in *Reesia* and *Monochytrium*. The zoospores are discharged through very short wartlike exit beaks, of which four or five may develop on a single sporangium, though only one functions.

In its cytology this organism is so similar to *Monochytrium* as to make it evident that the two are very closely related, although in the latter the spores

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[17] HOUARD, C., Les collections cécidologiques du laboratoire d'entologie du Museum d'Histoire Naturelle de Paris: l'herbier du Dr. Fairmaire. Marcellia **11**:11–46. 1912; and Galles de Mayr et Muller. Marcellia **11**:107–114. 1912.

[18] VAN LEEUWEN-REIJNVAAN, W. DOCTERS and J., Einige gallen aus Java. VI. Marcellia **11**:49–100. 1912.

[19] KUSANO, S., On the life history and cytology of a new *Olpidium* with special reference to the copulation of motile isogametes. Jour. Coll. Agric. Tokyo **4**:141–199. *pls. 15–17. fig. 1.* 1912.

do not conjugate until after infection. The nuclei of the zoosporangium divide during the growth stages by a process of amitosis like that figured by the writer in *Monochytrium*, but in the later reproductive stages they divide by mitosis, recalling conditions in *Synchytrium* and *Chrysophlyctis*. Fusion of the gametic nuclei in the zygote is delayed until the spring of the following year, the resting spores having of course matured in the meantime. Before they conjugate, however, they undergo a very peculiar process of budding by which large amounts of chromatin are extruded into the cytoplasm and central vacuole. The first division of the fusion nucleus appears to represent reduction, after which the nuclei are multiplied rapidly until the old resting spore becomes a zoosporangium very similar to the temporary sporangia.

The demonstration of such a primitive type of sexuality in *Olpidium* would seem to indicate clearly that it and its allies cannot be considered as having degenerated from higher fungi under "the debasing influence of parasitism." On the other hand, the facts so far brought to light do not give a clear indication of the source from which these forms may have come. It is evident, however, that they are polyenergid in contrast with *Synchytrium*, *Woroninella*, and *Chrysophlyctis*, which are essentially monoenergid, becoming coenocytic only during the reproductive period. KUSANO points out that this fact rules out the monoenergid Endosphaeraceae as indicative of the line of descent of *Olpidium*, though not necessarily eliminating the lower Protococcoideae in the region of *Chlamydomonas*. Now that cytological studies of the Archimycetes are beginning to accumulate, it is becoming increasingly evident that they represent not a single phylum, but a conglomeration of heterogeneous forms which have little in common except their apparent simplicity.—ROBERT F. GRIGGS.

Physiological effect of Bordeaux mixture.—Aside from its fungicidal value, Bordeaux mixture has been reported by several investigators to have a physiological action which results in an increased assimilatory activity of sprayed plants. This action has been further investigated by EWERT, who in a former paper reported experiments which indicate that, contrary to the generally accepted opinion, the physiological effect of Bordeaux mixture on the leaves of plants is detrimental. In the present paper EWERT[20] reports the results of an investigation of the effects of Bordeaux mixture on the assimilatory activity of the potato, radish, and bean; and on the sugar content of currants. The experiments with potatoes, radishes, and beans were conducted with plants grown in tanks under controlled conditions, and in soil kept at a constant water content. It was found that almost without exception the yield of tubers, roots, and pods, and of total dry matter was depressed by a covering of

[20] EWERT, R., Weitere Studien über die physiologische und fungicide Wirkung der Kupferbrühen bei krautigen Gewächsen und der Johannisbeere. Zeitschr. Pflanzenkrank. **22**:257–285. 1912.

Bordeaux mixture on the leaves. The depression of the yield increased with the strength of the mixture applied. As a rule, the beneficial effect of the mixture has been ascribed to the shade-effect of the covering, which was supposed to protect the plants from too great an intensity of light. EWERT found that bean plants shaded by a light gauze during periods of greatest illumination gave a greater yield and retained their leaves longer than unshaded plants. A similar effect produced by a covering of Bordeaux mixture, he thinks, would be counterbalanced by the ill effects of the shade on cloudy days and the toxic effects of the copper. In the experiments with currants, it was found that spraying berries with Bordeaux mixture or dipping them into it increased their sugar content considerably. How this effect is brought about is not yet clear. This effect on the berries is so striking that a decrease in their sugar content, due to depression of the assimilatory activity resulting from spraying the leaves, can be easily overlooked. Two sprayings of the leaves with 4 per cent mixture resulted only in a decrease of 0.5 per cent in the sugar content of the berries which were protected from the spray. This decrease is attributed to the deleterious effects of the mixture on the assimilatory activity of the leaves.—H. HASSELBRING.

Dispersal of seeds by ants.—SERNANDER[21] organized the disjointed and inaccurate data on the importance of ants in the distribution of certain seeds and fruits, and added a wealth of observations and experimental evidence upon this phase of ecological science. This particular kind of distribution he termed "myrmecochorous," and showed that it was almost wholly due, not to the supposed mimicry of the pupa of ants by the seeds, but to the presence of certain oil bodies or "elaiosomes" which serve as food for the ants and hence cause their collection and storage. These bodies occur as various morphological modifications or appendages of seeds and fruits, various types being distinguished. Some 120 plants were at that time listed as myrmecochorous, and evidence was produced that the activity by a single colony of ants for one season includes the transportation of many thousand seeds, some to distances of 15 to 70 meters.

A recent article by MORTON[22] calls attention to the important foundation laid by SERNANDER, cites the contributions that have appeared since that date, and summarizes the present situation of myrmecochory. The number of myrmecochorous plants has been considerably increased, although these studies have been almost exclusively confined to Europe. The associations affected are mostly those of woodland and ruderal plants. MORTON concludes that ants have been acting as a selection factor for such plants at least since

[21] SERNANDER, R., Entwurf einer Monographie der europäischen Myrmekochoren. Kungl. Vetensk. Akad. Upsala **41**: 1906.

[22] MORTON, FRIEDRICH, Die Bedeutung der Ameisen für die Verbreitung der Pflanzensamen. Mitt. Naturwiss. Vereins 1912:77–112. Reprint by author, 1913.

the Tertiary age, and that the center of distribution of woodland forms has been the forests of central Europe, while ruderal myrmecochorous forms have radiated from the Mediterranean region. The elaiosomes, in his opinion, have originated in many ways quite independently of the purpose they now serve as factors in distribution.—GEO. D. FULLER.

Anisophylly.—In *Strobilanthes anisophyllus* FIGDOR,[23] experimenting to discover the cause of the development of isophyllous shoots, is satisfied that it is a reversion to juvenile form because seedlings show no anisophylly until they have attained considerable size, and he thinks that it should be possible to prolong isophyllous development indefinitely. He agrees with BOSHART[24] that good nutrition tends to promote isophylly, but takes exception to his statement that anisophylly is to be explained through dorsiventrality. BOSHART[25] in a more recent paper lays emphasis on his former points, such as the asymmetry of the growing point of anisophyllous shoots and the very slight effect of gravity and light. He thinks that the latter factor may affect anisophylly through increasing or decreasing the vigor of the shoot, the weakening favoring asymmetry. He finds, on the contrary, light exercising a direct influence upon the anisophylly of certain species of *Selaginella* and *Lycopodium*.

Anisophyllous rosettes in various species of *Sempervivum* have been experimentally shown by DOPOSCHEG-UHLÁR[26] to result from an inclination of the stem axis toward the horizontal, but whether the response was effected by gravity or light he was unable to determine. The anisophylly seems to disappear toward the close of the growing season and to be renewed early the following spring. The phenomenon in nature is closely associated with the crowded grouping of young plants about the parent rosette in the characteristic multiplication by offshoots.—GEO. D. FULLER.

Morphology of Agathis.—EAMES[27] has investigated the Kauri, the famous timber tree of the Australasian region. Our knowledge of the morphology of the araucarians has lagged behind that of the other coniferous tribes, so that this contribution is very timely. An outline of the results is as follows. Pollination occurs a year after the appearance of the ovulate strobili, and fertiliza-

[23] FIGDOR, W., Das Anisophyllie-Phaenomen bei Vertretern des Genus *Strobilanthes* Blume. Ber. Deutsch. Bot. Gesells. **29**:549–558. 1911.

[24] BOSHART, K., Beiträge zur Kenntnis der Blattasymmetrie und Exotrophie. Flora **103**:91–124. 1911.

[25] BOSHART, K., Über die Frage der Anisophyllie. Ber. Deutsch. Bot. Gesells. **30**:27–33. 1912.

[26] DOPOSCHEG-UHLÁR, J., Die Anisophyllie bei *Sempervivum*. Flora **105**:162–183. 1913.

[27] EAMES, ARTHUR J., The morphology of *Agathis australis*. Ann. Botany **27**:1–38. *figs. 92. pls. 1–4.* 1913.

tion 13 months after pollination. The numerous archegonia are scattered over the broader micropylar portion of the gametophyte. The pollen grains germinate in the axils of the cone scales, before there is any differentiation of a micropyle. The pollen tubes are long and branching and penetrate the cone axis, and also the phloem and even the xylem of the scale traces. The two sperms are somewhat unequal cells with delicate walls, and their nuclei are as large as the egg nucleus. The proembryo is three-tiered, the uppermost tier forming the suspensor, the middle tier the embryo, and the lowest tier a protective cap. The cone scale is said to be structurally double, representing a combination of the bract and scale in Abietineae. It is concluded that the araucarians represent a highly specialized branch of the Coniferales, and that *Araucaria* is probably more ancient than *Agathis*.—J. M. C.

Anatomy of Botrychioxylon.—SCOTT[28] has described in detail the anatomy of *Botrychioxylon*, one of the paleozoic Zygopterideae. As in all the members of this family, a true pith is absent, the primary wood of the stele being intermixed with much parenchyma. Around the whole primary cylinder, as well as around the diarch leaf-trace, is a wide zone of secondary wood, a condition rare or absent in most of the family. The petiolar bundle resembles somewhat that of *Dineuron* or *Metaclepsydropsis*. Because of the unusual development of secondary wood, *Botrychioxylon* is considered by its author to approach the living *Botrychium* more closely than has any previously described form, and to present evidence for the affinity of the Zygopterideae and Ophioglossaceae. This conclusion is in harmony with that general theory, now the subject of much dispute, which derives the true pith of modern ferns from tissue which was primitively stelar.—E. W. SINNOTT.

Fertilization in Gagea.—In *Gagea lutea*[29] the usual double fertilization is the rule, but occasionally both male nuclei fuse with the egg. Another apparently unusual feature is the inclusion of cytoplasm between the fusing nuclei both during the fertilization of the egg and during the fusion of the polar nuclei. The included cytoplasm soon disorganizes. This is the second record of such a cytoplasmic inclusion, the first having been made by BROWN[30] in his study of *Peperomia*. The dispermic fertilization and a study of the literature of chromosome numbers leads NĚMEC into speculations upon the origin of mutation.—CHARLES J. CHAMBERLAIN.

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[28] SCOTT, D. H., On *Botrychioxylon paradoxum*, sp. nov., a paleozoic fern with secondary wood. Trans. Linn. Soc. Bot. **7**:373–389. *pls. 37–41*. 1912.

[29] NĚMEC, B., Über die Befruchtung bei *Gagea*. Bull. Internat. Acad. Sci. Bohême 1912:1–17. *figs. 19*.

[30] BROWN, W. H., The exchange of material between nucleus and cytoplasm in *Peperomia sintenisii*. BOT. GAZ. **49**:189–194. *pl. 13*. 1910.

GENERAL INDEX

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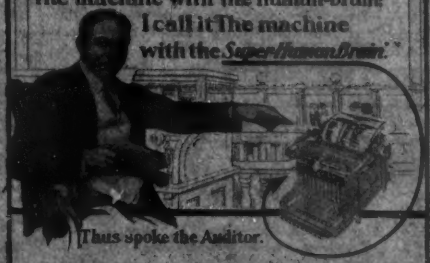

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